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Revision 1

REMEDIAL INVESTIGATION/ FEASIBILITY STUDY WORK PLAN FOR THE 200-BP-5 GROUNDWATER OPERABLE UNIT

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

United States
Department of Energy
P.O. Box 550
Richland, Washington 99352

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CONCURRENCE PAGE

Title: Remedial Investigation/Feasibility Study Work Plan for the 200-BP-5 Groundwater Operable Unit, Hanford Site, Richland, Washington

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EXECUTIVE SUMMARY

This work plan defines the approach, tasks, and schedules associated with the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980*[1] remedial investigation/ feasibility study (RI/FS) activities for the 200-BP-5 Groundwater Operable Unit (OU). This document describes the 200-BP-5 Groundwater OU setting and preliminary conceptual site model (CSM) and provides an initial evaluation of the groundwater OU in the context of the CSM. The work plan also provides rationale for the RI/FS activities summarized in this document and detailed in the associated sampling and analysis plan (Appendix A). This work plan supports the selection process to determine a final remedy for the 200-BP-5 Groundwater OU, as agreed upon by the U.S. Department of Energy (DOE), Richland Operations Office, and the U.S. Environmental Protection Agency (EPA).

The main objectives of the 200-BP-5 Groundwater OU RI/FS work plan are to provide the necessary information and data for the following purposes.

- Refine the CSM describing the groundwater contamination sources, nature, and extent of groundwater contamination, and potential exposure scenarios.
- Support the future baseline risk assessment.
- Support the evaluation of remedial alternatives as part of the feasibility study (FS).

Activities conducted under this work plan will conform to the conditions set forth in Ecology et al., 1989a, *Hanford Federal Facility Agreement and Consent Order* (Tri-Party Agreement)[2] and amendments signed by the Washington State Department of Ecology, EPA, and the U.S. Department of Energy, Richland Operations Office.

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[1] *Comprehensive Environmental Response, Compensation, and Liability Act of 1980*, 42 USC 9601, et seq.

[2] Ecology, EPA, and DOE, 1989a, *Hanford Federal Facility Agreement and Consent Order*, 2 vols., as amended, Washington State Department of Ecology, U.S. Environmental Protection Agency, and U.S. Department of Energy, Olympia, Washington.

The work plan carries forth information and scoping objectives developed during the data quality objectives process, as documented in WMP-28945, *Data Quality Objectives Summary Report in Support of the 200-BP-5 Groundwater Operable Unit Remedial Investigation/Feasibility Study Process.*[3]

The scope of the field investigations described in this work plan support multiple objectives. The main objective of this work plan is the collection of sufficient data to support a risk assessment and allow the ultimate selection of one or more appropriate remedial alternatives. Various data-collection activities will be used to further delineate the nature and extent of groundwater contamination to build a defensible risk model that will allow screening of remedial alternatives.

The work plan includes descriptions of the 200-BP-5 Groundwater OU's geographic and geologic setting, as well as the overlying operational history of the area's various facilities. A preliminary CSM is provided with a discussion of contaminant sources and migration pathways, which includes an initial evaluation of the groundwater chemistry within the OU. Data needs are identified along with project assumptions and data-collection activities. Project tasks are provided with detailed information on characterization investigations, monitoring activities, and approaches to data evaluation and analyses. Next, a discussion is provided on the content and use of the final remedial investigation (RI) report, baseline risk assessment, and FS to be developed after completion of this work plan. Finally, the schedule for these characterization activities is followed by a detailed SAP (Appendix A). The SAP includes the quality assurance project plan, which provides the quality assurance and quality control requirements for data collection and evaluation. The quality assurance project plan establishes the quality requirements for environmental data collection, including sampling, field measurements, and laboratory analyses.

To facilitate the complexities of describing numerous waste and processing sites, the 200-BP-5 Groundwater OU was subdivided into nine individual sub-areas, which allow a graphical representation to orient the reader toward a specific geographic area rather than using

[3] WMP-28945, 2007, *Data Quality Objectives Summary Report in Support of the 200-BP-5 Groundwater Operable Unit Remedial Investigation/Feasibility Study Process*, Rev. 0, Fluor Hanford, Inc., Richland, Washington.

the numerous waste sites, buildings, and well locations as reference points. A map of the OU with each of the sub-areas delineated inside the OU boundary is provided. The sub-areas are not intended for use in bisecting either the CSMs or the baseline line risk assessment. In addition, the sub-areas will not be used for evaluating remedial alternatives.

The boundaries of the 200-BP-5 Groundwater OU encompass an area of approximately 84.5 km^2 (32.6 mi^2), underlying mostly undeveloped land, with clusters of industrial buildings and associated structures. The buildings and structures primarily are located within the fence line of the 200 East Area. WMP-28945 contains a thorough review of the documents relevant to the 200-BP-5 Groundwater OU, including process history, waste-site information, vadose zone studies, and groundwater investigations. The site setting and background information provided in this document are relevant to the RI/FS work-planning effort and support the rationale for the work plan activities. This information includes the overlying site geography and geology, the geology and hydrogeology of the 200-BP-5 Groundwater OU, and a review of the potential overlying contaminant waste sources according to sub-area.

The CSM provides the general framework for describing surface and subsurface conditions to guide decision making. This includes contaminant sources, stratigraphy and hydrogeologic conditions, relevant geochemistry and soil interactions, and characterization of the 200-BP-5 Groundwater OU contaminant plumes. The major elements of the CSM are contaminant sources, migration pathways, contaminated media (i.e., groundwater), and receptors. Each of these elements is evaluated relative to the 200-BP-5 Groundwater OU. In addition, the primary data needs for each element are summarized as a basis for development of the work plan activities.

Localized occurrences of contaminated soils in the vadose most likely are the primary sources of current contamination that currently may be entering the groundwater. The major sources of these contaminated soils in the 200-BP-5 Groundwater OU include intentional liquid discharges to cribs, ponds, and ditches; injection wells; accidental spills and releases; and leaking single-shell tanks (SST) and ancillary equipment. In the past, contamination has migrated to the groundwater through percolation or infiltration via the vadose zone (as evidenced by high levels of groundwater contamination) or was injected directly via injection wells. The Columbia River and West Lake are the only surface-water bodies that potentially could be impacted from contaminated groundwater derived from sources in the 200-BP-5 Groundwater OU.

The primary sources known or strongly suspected of contributing to groundwater contamination in the 200-BP-5 Groundwater OU are the BY Cribs, SSTs and ancillary equipment, spills within Waste Management Area (WMA) B/BX/BY and WMA-C Tank Farms, the 216-B-5 Reverse Well, and the 216-B-8 Crib. In addition to these sources, vadose zone contamination likely to pose a significant threat to groundwater quality is suspected below the 216-B-12 and 216-C-1 Cribs and the 216-B-6 Reverse Well.

Data needs pertaining to the contaminant pathway evaluation include the following.

- Vadose zone and groundwater data are needed in the vicinity of tank 241-BX-102 (see UPR-200-E-5 in Figure 2-10) and the BY Crib complex to help identify the nature and extent of deep vadose zone contamination and the associated groundwater contamination in these local areas.

- Additional data are required to delineate the source or sources of contaminated soils contributing to uranium contamination in the groundwater beneath the WMA-B/BX/BY Tank Farm and the 216-B-8 Crib.

- Vadose zone data are needed to further investigate the source of significant uranium concentrations found near the 216-B-7A Crib. A recent spectral-gamma log of nearby well 299-E33-18 shows increases in uranium levels within a silt zone close above the water table.

- Additional data are necessary to delineate possible sources associated with increasing concentrations of nitrate and technetium-99 in the WMA-C Tank Farm groundwater-monitoring wells.

- Further investigation of deep vadose zone contamination associated with the 216-B-12 Crib is required to predict potential future impacts to groundwater quality.

- Near the 216-C-1 Crib, analyses of deep vadose zone soils may be necessary to understand or predict potential future groundwater impacts.
- Additional data, including deep vadose zone sediment data, are necessary in the vicinity of the 216-B-6 Reverse Well to investigate whether groundwater north of the reverse well is contaminated from past releases.

Contaminant transport through the vadose zone and aquifer is influenced by a number of geochemical, hydrologic, and physical factors. Primary factors influencing contaminant migration in the 200-BP-5 Groundwater OU are critical to evaluating risks to receptors from existing and potentially emerging groundwater contamination. The primary factors influencing contaminant movements in both the vadose zone and the aquifer systems include the geologic stratigraphy, migration pathways of contaminants, recharge (or deep infiltration), groundwater flow rates and direction, and physical/geochemical properties of the sediments.

Data investigative needs pertaining to contaminant pathway evaluation include the following.

- Acquire borehole log data, which reveal the depth, thickness, and possible lateral extent of significant low-permeability sediment layers in the Hanford formation and Pliocene/Pleistocene units in the vicinity of the WMA-B/BX/BY Tank Farm and BY Cribs, as well as other areas where contaminant sources pose a significant risk to groundwater quality.
- Measure physical and geochemical soil properties affecting contaminant transport within key strata in the vadose zone to aid in modeling potential future impacts.
- Identify poorly sealed or unsealed older wells that may be allowing preferential vertical flow through the vadose zone.
- Identify the nature and extent of deep vadose zone contamination in the vicinity of the WMA-B/BX/BY Tank Farm and the BY Cribs.
- Ascertain groundwater flow direction(s) and basalt elevations, where needed, in the unconfined and confined aquifers.

- Identify potential migration of contaminants from the overlying unconfined to the uppermost confined aquifer, the Rattlesnake Ridge interbed, including specific well 299-E33-12 and well series 699-53-55 located in the erosion window of the Elephant Mountain Member of the Saddle Mountain Basalt formation.

- Measure physical and geochemical soil properties affecting aqueous-phase contaminant transport.

Contamination of groundwater in the 200-BP-5 Groundwater OU is widespread in the unconfined aquifer. Numerous chemical and radiological contaminants have been detected in monitoring wells for decades. Contamination in the Rattlesnake Ridge interbed confined aquifer (also known as the uppermost basalt confined aquifer) is present, but the extent is not known due to the limited number of wells monitoring the aquifer itself. The apparent distribution of groundwater contamination as currently understood for each of the 200-BP-5 Groundwater OU contaminants, identified above the maximum contaminant level, is presented.

The most widely distributed groundwater contaminants in the 200-BP-5 Groundwater OU are tritium, nitrate, technetium-99, and iodine-129. Contaminants mostly confined to localized areas in the OU are strontium-90, cesium-137, plutonium-239/240, uranium, sulfate and cyanide.

WIDESPREAD CONTAMINANTS OF POTENTIAL CONCERN

The widespread contaminants of potential concern are discussed below.

- Tritium contamination is widespread throughout the western portion of the 200 East Area. The contamination extends north through the gap between Gable Mountain and Gable Butte, to the Columbia River, and southeast through the 200-PO-1 Groundwater OU. Tritium contamination has declined within the 200-BP-5 Groundwater OU for several reasons. Part of the contamination appears to have migrated through the gap toward the river, while the tritium contamination in the northwestern corner of the 200 East Area appears to have migrated to the southeast. Tritium has declined partly due to natural decay (the half-life of tritium is 12.3 years) and partly due to dispersion.

- A nitrate plume originating from sources within the 200 East Area has migrated northwest from the 200 Areas toward the Columbia River. Currently, the distribution within the northwestern corner of the 200 East Area has been interpreted to have three parts: (1) a western plume associated with the high tritium seen in the past and discussed above, which extends through the west portion of Low-Level Waste Management Area 1; (2) an eastern plume that extends from the BY Cribs and surrounding cribs toward the northwest; and (3) a southern plume extending beneath the southern portion of the BY Cribs and surrounding cribs to the south.

- Technetium-99 contamination extends from the area of the WMA-B/BX/BY Tank Farm and the BY Cribs to the northwest, into sub-area #3 (north of the 200 East Area) at concentrations above the drinking water standard (DWS) of 900 pCi/L. The plume has moved through Gable Gap at levels below the DWS. Technetium-99 above the DWS also is found south of the BY Cribs. In recent years, increasing technetium-99 levels above the DWS have been observed near the WMA-C Tank Farm.

- Iodine-129 contamination appears present throughout the 200-BP-5 Groundwater OU based on interpretations of the groundwater data. Two plumes are tentatively identified. The Gable Gap iodine-129 plume is based on data from one well, while the more extensive 200 Area iodine-129 plume appears to be associated with the tritium contamination and extends to the 200-PO-1 Groundwater OU. Levels greater than the DWS (1 pCi/L) have not passed beyond the gap between Gable Mountain and Gable Butte.

LOCALIZED CONTAMINANTS OF POTENTIAL CONCERN

The localized contaminants of potential concern are discussed below.

- Uranium contamination in the 200-BP-5 Groundwater OU is limited to monitoring wells in three isolated areas: the WMA-B/BX/BY Tank Farm and BY Cribs and stretching to the northwest corner of Low-Level Waste Management Area 1, near the 216-B-5 Injection Well, and near the 216-B-62 Crib. Wells in all three areas exceeded the uranium DWS of 30 μg/L.

- Cyanide is found at levels above the DWS (200 µg/L) and continues to be detected in two locations in the 200-BP-5 Groundwater OU. The highest values are seen under the BY Cribs in sub-area #4, while values under the DWS of 200 µg/L are seen at the WMA-C Tank Farm in sub-area #6.

- Strontium-90 has relatively low mobility and generally is found in groundwater proximal to near-surface disposal facilities. Strontium-90 primarily occurs in two groundwater locations in the 200-BP-5 Groundwater OU, below the Gable Mountain Pond site and near the 216-B-5 Reverse Well.

- Groundwater cesium-137 and plutonium-239/240 concentrations occur locally in the vicinity of the 216-B-5 Reverse Well.

- Sulfate is found at levels above the DWS (250 mg/L) in one well under the BY Cribs. Sulfate also is detected along the southeastern portion of Low-Level Waste Management Area 2.

The following activities are needed to improve the understanding of the nature and extent of 200-BP-5 Groundwater OU groundwater contamination.

- Obtain additional monitoring wells and sediment data necessary to better define contaminant plume extent and geometry.

- More accurately define vertical variations in unconfined aquifer contaminant concentrations.

- Monitor the wells in Gable Gap to obtain data to calculate the mass transfer of contaminants north of Gable Gap. As water levels decline, net movement of groundwater north is expected to decline.

- More accurately define the contaminant distributions in the unconfined aquifer plotting values above and below maximum contaminant levels.

- Install monitoring wells north and south of well 299-E33-12 to increase knowledge of contaminants detected in the Rattlesnake Ridge confined aquifer.
- Map contaminant concentrations within the confined aquifer zones, including the Ringold confined aquifer and the Rattlesnake Ridge confined aquifers.

An important criterion for identifying potential risk to receptors is determining the current and reasonably anticipated future land use for the Hanford Site. DOE's intention is to restore the groundwater beneath the Hanford Site to its highest beneficial use. Because the final land use has not been determined, a variety of restricted- and unrestricted-use-exposure scenarios will be evaluated in the FS. Exposure scenarios will include drinking water and other potable water uses for potential industrial workers, future potential rural residents, and future Native American Subsistence Lifeway receptors. The development of the conceptual models for the Central Plateau and other areas of the Hanford Site is ongoing and will be incorporated as updates to the preliminary CSM, as available.

The activities that will be conducted with this work plan are closely tied to the following overall objectives of the 200-BP-5 Groundwater OU RI/FS.

- Refine the CSM describing the groundwater contamination sources, the nature and extent of groundwater contamination, and potential exposure scenarios.
- Obtain data required to support the future baseline risk assessment, which is part of the RI. Integrated investigations to obtain these data are focused on both the vadose zone and the groundwater system. However, because separate risk assessments are being conducted at surface OUs, the 200-BP-5 Groundwater OU will focus on the groundwater portion.
- Provide information sufficient to support an evaluation of remedial alternatives as part of the FS. Integrated investigations to obtain this information are focused on both the vadose zone and the groundwater system. Contaminant distributions, contaminant trends, groundwater pathways, and geochemical effects on future contaminant concentrations should be investigated.

Numerous project assumptions, which relate to the general RI/FS project, contaminant sources, contaminant movement and pathways, exposure scenarios and pathways, and project schedule, are described in this work plan. Project assumptions provide context to the conditions, expectations, and constraints by which the 200-BP-5 Groundwater OU RI/FS project is planned and implemented. Key project assumptions are described in WMP-28945, which addresses issues of the OU boundaries, remedial actions, risk assessment and modeling, vadose zone information, well locations and objectives, characterization and testing, schedule, and decision makers.

The characterization activities described in this work plan are categorized into the following major tasks:

- Drilling and construction of new wells
- Sampling vadose zone sediment
- Sampling of depth-discrete aquifer sediment and groundwater during borehole drilling
- Performing geophysical investigations (surface and borehole methods)
- Performing aquifer hydrologic testing
- Performing groundwater monitoring using existing and new wells.

Sample collection methods, depths, and frequency, as well as performance requirements, are described in detail in the SAP (Appendix A).

The vadose zone investigation discussed in this work plan is an integrated effort with multiple vadose zone OUs and tank farm WMAs. These activities have been coordinated through integrated project team meetings. The integrated project team consists of technical project leads from the DOE and its major subcontractors.

The primary activities to be implemented for the 200-BP-5 Groundwater OU RI are summarized as follows.

- Fifteen new monitoring wells will be drilled in the 200-BP-5 Groundwater OU. Groundwater samples will be collected and analyzed for a combination of contaminants of potential concern and those constituents previously identified which currently exceed the groundwater DWS. The proposed well locations were selected with the following five goals: (1) define potential contamination in the vadose zone, (2) determine the vertical and horizontal extent of groundwater contamination, (3) map the key geologic strata influencing contamination migration, (4) measure aquifer characteristics, and (5) define groundwater flow directions.

- Deep vadose zone sediment samples will be collected and analyzed to improve the understanding of contaminant pathways in the vadose zone near waste sites. Deep vadose generally is defined as those soils above the water table that are deeper than 30.5 m (100 ft) below ground surface.

- Deep vadose zone unsaturated sediment samples and saturated aquifer sediment samples will be analyzed for geochemical and physical characteristics to better understand contaminant fate and transport.

- Aquifer tests will be conducted where existing aquifer parameter information is lacking.

- An enhanced sampling program will be developed for the network of 92 existing groundwater-monitoring wells. This program will augment groundwater quality information obtained by the new RI wells and will specifically focus on groundwater contaminants of potential concern, and key macro constituents that influence the fate of contaminants of potential concern.

- High-resolution resistivity surveys are being conducted near high-level waste sites, including the SST farms, to help determine optimal borehole locations and to possibly better understand contaminant pathways in the vadose zone.

- Supplemental information from research, monitoring, and characterization efforts that are conducted for other programs will be incorporated as available, including (but not limited to) *Resource Conservation and Recovery Act of 1976*[4] sampling and analysis activities; collection of water-level measurements; collection of pH, temperature, and conductivity

[4] *Resource Conservation and Recovery Act of 1976*, 42 USC 6901, et seq.

readings; implementation of quality assurance activities (e.g., Washington State Department of Health co-sampling); and possibly research activities.

- An integrated project team has been developed to integrate and coordinate all groundwater and vadose zone investigations concerning uranium and technetium-99 distributions in the vicinity of the WMA-B/BX/BY Tank Farm and surrounding cribs, trenches, french drains, and reverse well waste sites.

Characterization data will be evaluated using the EPA's risk assessment guidance as a key component to the RI/FS process (EPA/540/1-89/002, *Risk Assessment Guidance for Superfund, Volume I -- Human Health Evaluation Manual, (Part A) Interim Final,* OSWER 9285.7-01A [5] and DOE/RL-91-45, *Hanford Site Risk Assessment Methodology*[6]). Data evaluation will occur before use in developing the final CSM and before incorporating the data into the baseline risk assessment or remedial alternative evaluation during the FS.

Deliverables to be prepared following the RI characterization efforts include an RI report with a baseline risk assessment, and an FS. The RI report will provide a descriptive summary of all site investigations conducted within the OU. The RI report includes analyses of the ongoing activities, data collection performed as part of interim measures, and data sets generated as a result of the characterization activities performed, as described in this work plan. The baseline risk assessment will evaluate the current and potential threats to human health and the environment posed by contaminants remaining in the soil, leaching through soil, migrating to groundwater, and potentially migrating to surface water.

The information from the RI and baseline risk assessment will be used to execute the FS in three phases: (1) develop alternatives, (2) screen alternatives, and (3) perform detailed analyses of alternatives. General response actions will be developed based on results of the RI and FS. These actions may be taken singly or in combination (e.g., pumping and ex situ treatment of

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[5] EPA/540/1-89/002, 1989, *Risk Assessment Guidance for Superfund (RAGS), Volume I -- Human Health Evaluation Manual, (Part A) Interim Final,* OSWER 9285.7-01A, U.S. Environmental Protection Agency, Washington, D.C.

[6] DOE/RL-91-45, 1995, *Hanford Site Baseline Risk Assessment Methodology*, Rev. 3, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

groundwater) to satisfy the remedial action objectives for the 200-BP-5 Groundwater OU. The following six preliminary alternatives are reviewed:

- No action
- Institutional controls
- Monitoring natural attenuation
- Permeable or impermeable containment
- Pump-and-treat
- Potential future alternatives.

The proposed plan will identify a preferred alternative and present the alternative to the public for review and comment. The proposed plan also will provide a summary of the investigations for the 200-BP-5 Groundwater OU, data generated from the various investigations, and conclusions derived from the data. The proposed plan will summarize the results of the FS and the basis for the action(s) proposed to remediate the site. It will include a summary of the remedial action, as well as a schedule for implementing the proposed plan.

A record of decision for the 200-BP-5 Groundwater OU will be obtained through the RI/FS process using data collected in accordance with this work plan. It is anticipated that the scope of this project, and to some extent the specific project plans, will be developed iteratively. As new information is acquired or new decisions are made, data requirements will be reevaluated and, if appropriate, the project plan will be modified.

This work plan is in support of Tri-Party Agreement Milestone M-015-00C, which requires the completion of all 200 Area non-tank farm OU site investigations under approved work plan schedules through submittal of FS reports and recommended remedies by December 31, 2011. Tri-Party Agreement Milestone M-015-21A requires submission of the 200-BP-5 Groundwater OU FS report and proposed plan by October 31, 2010.

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CONTENTS

PLATE

APPENDICES

FIGURES

TABLES

TERMS

AEA	*Atomic Energy Act of 1954*
bgs	below ground surface
CERCLA	*Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
COC	contaminant of concern
COPC	contaminant of potential concern
CRBG	Columbia River Basalt Group
CSM	conceptual site model
DOE	U.S. Department of Energy
DQO	data quality objective
DWS	drinking water standard
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
ERDF	Environmental Restoration Disposal Facility
FFTF	Fast Flux Test Facility
FH	Fluor Hanford, Inc.
FS	feasibility study
FY	fiscal year
H_1	Hanford formation gravel-dominated facies
H_2	Hanford formation sand-dominated facies
H_3	Hanford formation gravel-dominated facies
HEIS	*Hanford Environmental Information System* database
HRR	high-resolution resistivity
IX	ion-exchange
K_d	distribution coefficient
K_h	hydraulic conductivity
LERF	Liquid Effluent Retention Facility
LLWMA	low-level waste management area
MCL	maximum contamination level
MNA	monitored natural attenuation
OU	operable unit
QA	quality assurance
PUREX	Plutonium-Uranium Extraction (Plant or process) (tributyl phosphate solvent extraction)
QAPjP	quality assurance project plan
RCRA	*Resource Conservation and Recovery Act of 1976*
REDOX	Reduction-Oxidation (Plant or process) (hexone-based solvent extraction)
RFI/CMS	remedial field investigation/corrective measures study
RI	remedial investigation
RL	U.S. Department of Energy, Richland Operations Office
SALDS	state-approved land-disposal site
SAP	sampling and analysis plan
SST	single-shell tank

TBP	tributyl phosphate
TEDF	Treated Effluent Disposal Facility
Tri-Parties	U.S. Department of Energy, U.S. Environmental Protection Agency, and Washington State Department of Ecology
Tri-Party Agreement	*Hanford Federal Facility Agreement and Consent Order* (Ecology et al., 1989a)
TSD	treatment, storage, and disposal
UPR	unplanned release
WAC	*Washington Administrative Code*
WIDS	*Waste Information Data System* database
WMA	waste management area

METRIC CONVERSION CHART

Into Metric Units			Out of Metric Units		
If you know	*Multiply by*	*To get*	*If you know*	*Multiply by*	*To get*
Length			**Length**		
inches	25.40	millimeters	millimeters	0.0394	inches
inches	2.54	centimeters	centimeters	0.394	inches
feet	0.305	meters	meters	3.281	feet
yards	0.914	meters	meters	1.094	yards
miles (statute)	1.609	kilometers	kilometers	0.621	miles (statute)
Area			**Area**		
sq. inches	6.452	sq. centimeters	sq. centimeters	0.155	sq. inches
sq. feet	0.0929	sq. meters	sq. meters	10.764	sq. feet
sq. yards	0.836	sq. meters	sq. meters	1.196	sq. yards
sq. miles	2.591	sq. kilometers	sq. kilometers	0.386	sq. miles
acres	0.405	hectares	hectares	2.471	acres
Mass (weight)			**Mass (weight)**		
ounces (avoir)	28.349	grams	grams	0.0353	ounces (avoir)
pounds	0.454	kilograms	kilograms	2.205	pounds (avoir)
tons (short)	0.907	ton (metric)	ton (metric)	1.102	tons (short)
Volume			**Volume**		
teaspoons	5	milliliters	milliliters	0.034	ounces (U.S., liquid)
tablespoons	15	milliliters	liters	2.113	pints
ounces (U.S., liquid)	29.573	milliliters	liters	1.057	quarts (U.S., liquid)
cups	0.24	liters	liters	0.264	gallons (U.S., liquid)
pints	0.473	liters	cubic meters	35.315	cubic feet
quarts (U.S., liquid)	0.946	liters	cubic meters	1.308	cubic yards
gallons (U.S., liquid)	3.785	liters			
cubic feet	0.0283	cubic meters			
cubic yards	0.764	cubic meters			
Temperature			**Temperature**		
Fahrenheit	(°F-32)*5/9	Centigrade	Centigrade	(°C*9/5)+32	Fahrenheit
Radioactivity			**Radioactivity**		
picocurie	37	millibecquerel	millibecquerel	0.027	picocurie

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1.0 INTRODUCTION

This work plan defines the tasks and schedules associated with the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) remedial investigation/feasibility study (RI/FS) activities for the 200-BP-5 Groundwater Operable Unit (OU). As the basis for the work plan tasks and schedule, this document describes the setting and preliminary conceptual site model (CSM) for the 200-BP-5 Groundwater OU and provides an initial evaluation of the groundwater OU in the context of the CSM. The work plan also provides rationale for the RI/FS activities summarized in this document and detailed in the associated sampling and analysis plan (SAP) (Appendix A). This work plan supports the final remedial alternative selection process for the 200-BP-5 Groundwater OU, as agreed upon by the U.S. Department of Energy (DOE), Richland Operations Office (RL), and the U.S. Environmental Protection Agency (EPA).

Figure 1-1 shows the location of the 200-BP-5 Groundwater OU at DOE's Hanford Site, located in Benton County, Washington. Figure 1-2 and Plate Map 1 (included after Chapter 7.0 of this document) show the entire 200-BP-5 Groundwater OU and its relationship to surrounding groundwater OUs. Collectively, the 200-BP-5 and 200-PO-1 Groundwater OUs contain all of the groundwater beneath the 200 East Area of the Hanford Site. The 200-BP-5 Groundwater OU extends from the 200 East Area to the Columbia River to the north, and to the east flank of the Gable Mountain to the east. The boundaries of the 200-BP-5 Groundwater OU encompass an approximate area of 32.6 mi^2 (84.5 km^2). The upper boundary of the 200-BP-5 Groundwater OU is the water table; however, vadose zone concerns above the OU will be addressed through sediment sampling and analysis that will be conducted as part of the installation of the 15 monitoring wells described in this work plan. In addition, vadose zone information obtained from ongoing monitoring and characterization activities for overlying *Resource Conservation and Recovery Act of 1976* (RCRA) treatment, storage, and disposal (TSD) units and source OUs will be integrated with the 200-BP-5 Groundwater OU RI, as made available. Vadose zone data and information will provide input to modeling and risk assessment activities in support of the baseline risk assessment and the feasibility study (FS).

Activities conducted under this work plan will conform to the conditions set forth in Ecology et al., 1989a, *Hanford Federal Facility Agreement and Consent Order* (Tri-Party Agreement) and amendments signed by the Washington State Department of Ecology (Ecology), EPA, and RL. This work plan is in support of Tri-Party Agreement Milestone M-015-00C, which requires the completion of all 200 Area non-tank farm OU site investigations under approved work plan schedules through submittal of FS reports and recommended remedies by December 31, 2011. Tri-Party Agreement Milestone M-015-21A requires submission of the 200-BP-5 Groundwater OU FS report and proposed plan by October 31, 2010.

Much of the background information, physical setting, conceptual model information, and contaminants of potential concern (COPC) are discussed in WMP-28945, *Data Quality Objectives Summary Report in Support of the 200-BP-5 Groundwater Operable Unit Remedial Investigation/ Feasibility Study Process* and other project documents and, thus, are not addressed in extensive detail in this work plan. Appendices A through D in WMP-28945 contain comprehensive lists of the major references that were reviewed as part of the scoping process, as well as a summary of the pertinent information contained within each reference. The goal of this work plan is two-fold: (1) summarize the relevant information from the vast amount of work performed to date, and (2) provide the basis for collection of additional data to support completing the RI/FS and risk assessment for selection of final remedial action(s) for the OU.

1.1 WORK PLAN PURPOSE, SCOPE, AND OBJECTIVES

The purpose of this work plan is to describe the approach for completing the RI/FS to support selection of a final remedy for the 200-BP-5 Groundwater OU. The scope of the fieldwork described in this work plan is the collection of data to better define the nature and extent of contamination in the groundwater OU, as well as to collect additional data needed to support risk modeling and screening of remedial alternatives. The objective of this work plan is the collection of sufficient data to support a risk assessment and to allow the ultimate selection of one or more appropriate remedial alternatives.

1.2 DATA QUALITY OBJECTIVES

The project used EPA/240/B-06/001, *Guidance on Systematic Planning Using the Data Quality Objectives Process*, EPA QA/G-4, to identify the data needs described in this work plan. Both EPA and RL participated in the community relations portion of the data quality objective (DQO) process, which established the assumptions and global issues associated with the 200-BP-5 Groundwater OU. WMP-28945 summarizes the outcome of the DQO process for the 200-BP-5 Groundwater OU.

1.3 DOCUMENT ORGANIZATION

This work plan contains seven chapters and two appendices. The main text of the work plan consists of the following chapters:

- Chapter 1.0 – Introduction
- Chapter 2.0 – Site Background and Setting
- Chapter 3.0 – Initial Evaluation of the 200-BP-5 Groundwater Operable Unit
- Chapter 4.0 – Work Plan Rationale
- Chapter 5.0 – Remedial Investigation/Feasibility Study Tasks
- Chapter 6.0 – Project Schedule
- Chapter 7.0 – References.

Appendix A contains the SAP pertaining to the majority of RI activities described in this work plan. In addition to the SAP, DOE/RL-2006-55, *Sampling and Analysis Plan for FY 2006 200-BP-5 Groundwater Operable Unit Remedial Investigation/Feasibility Study*, was issued to address RI activities initiated before completion of WMP-28945 and this work plan. Each SAP consists of a quality assurance project plan (QAPjP) and a field sampling plan.

Appendix B includes a table of the sampling and analysis requirements for the revised 200-BP-5 Groundwater OU monitoring well network.

1.4 QUALITY ASSURANCE

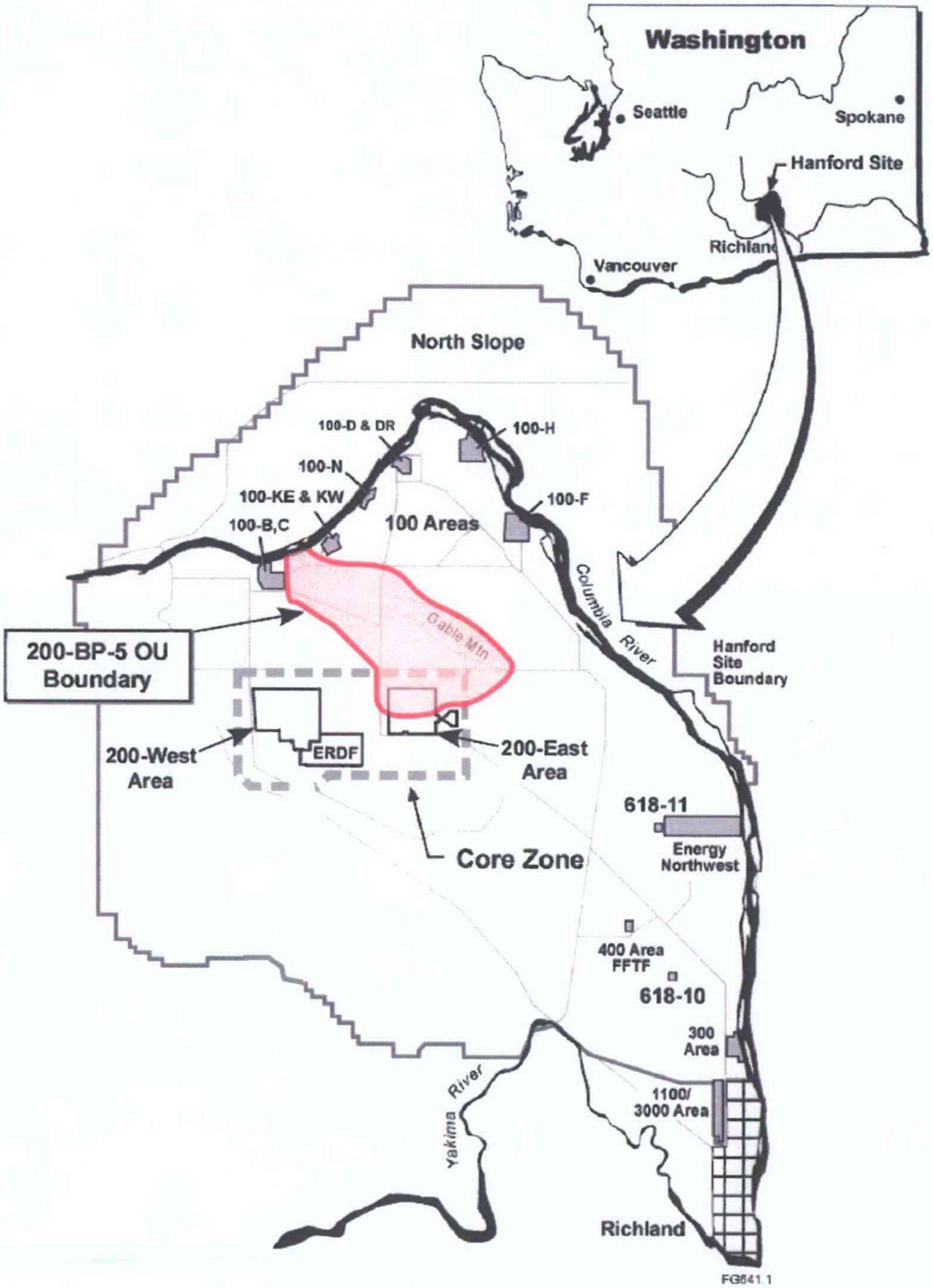
The QAPjP for the RI activities is presented in the SAP (Appendix A). The QAPjP includes details regarding the quality assurance (QA) and quality control required for data collection and evaluation, while the field sampling plan identifies the approach for collecting new data. The QAPjP establishes the quality requirements for environmental data collection, including sampling, field measurements, and laboratory analysis. The QAPjP complies with the requirements of the following:

- DOE O 414.1C, *Quality Assurance*
- 10 CFR 830, Subpart A, "Quality Assurance Requirements"
- EPA/240/B-01/003, *EPA Requirements for Quality Assurance Project Plans*, EPA QA/R-5.

The QA requirements are implemented according to the Fluor Hanford, Inc. (FH) internal QA program. The QA program description document describes how FH implements the QA requirements conveyed in DOE O 414.1C, *Quality Assurance*, "Contractor Requirements Document," and in 10 CFR 830 and how the Tri-Party Agreement and Hanford Site internal laboratory QA requirements apply to FH's environmental QA program plans.

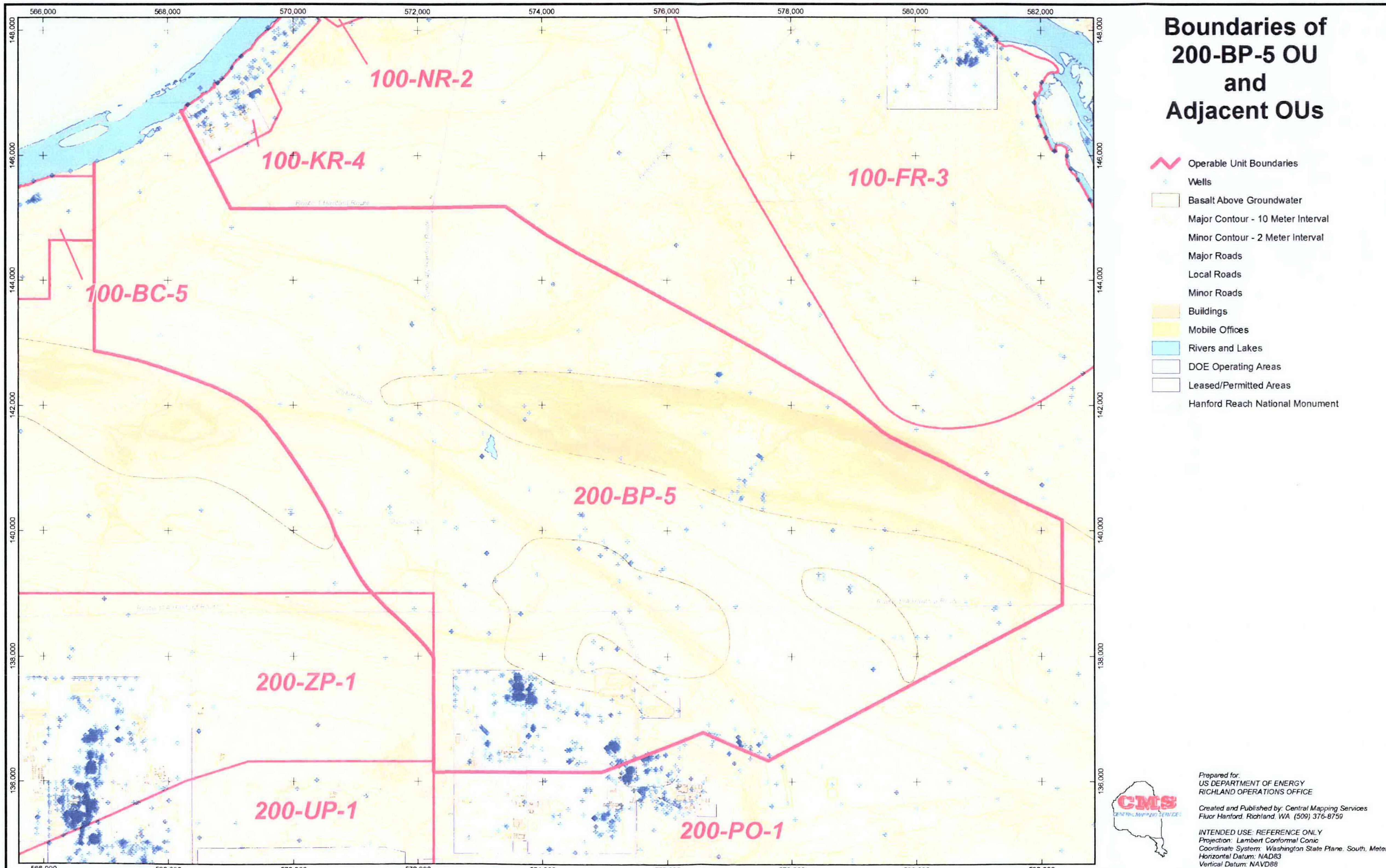
All work performed in support of the RI will be performed in compliance with the FH QA program plan, the FH Groundwater Remediation Project plan, or subsequent and equivalent FH quality program plans. Field sample collection and documentation activities will be performed according to applicable FH procedures.

Figure 1-1. Location of the 200-BP-5 Groundwater Operable Unit Within the Hanford Site.



ERDF = Environmental Restoration Disposal Facility.
FFTF = Fast Flux Test Facility.
OU = operable unit.

Figure 1-2. Boundaries of 200-BP-5 Groundwater Operable Units and Adjacent Operable Units.



2.0 SITE BACKGROUND AND SETTING

This chapter provides background and site setting information relevant to the 200-BP-5 Groundwater OU RI/FS planning process. A thorough review of the documents relevant to the 200-BP-5 Groundwater OU included process history, waste inventory, vadose zone studies, and groundwater studies conducted as part of the DQO process and is presented in the 200-BP-5 Groundwater OU DQO summary report (WMP-28945).

In 1989, the Hanford Site was listed on the National Priorities List (40 CFR 300, "National Oil and Hazardous Substances Pollution Contingency Plan," Appendix B, "National Priorities List") pursuant to CERCLA. To address groundwater issues in the 200 East Area, 200-BP-5 Groundwater OU and 200-PO-1 Groundwater OU areas were established. The 200-BP-5 Groundwater OU includes the groundwater beneath the northern part of the 200 East Area and north to the Columbia River, as shown in Figure 1-2. The OU underlies 72 CERCLA liquid effluent waste sites and the following five facilities, which have groundwater-monitoring requirements under RCRA and the *Atomic Energy Act of 1954* (AEA):

- Waste Management Area (WMA) B/BX/BY Tank Farms
- 216-B-63 Trench
- Low-Level Waste Management Area (LLWMA)-1 and -2
- Liquid Effluent Retention Facility (LERF)
- WMA-C Tank Farm.

For the purpose of this work plan, the 200-BP-5 Groundwater OU was subdivided into nine individual sub-areas. Subdividing the OU into sub-areas allows for better graphical presentation of the OU and helps orient the reader toward a specific overlying geographic area rather than using the numerous waste sites, buildings, and well locations as reference points. Figure 2-1 contains a map of the surface expression overlying the OU with each of the sub-areas delineated within the OU boundary. The sub-areas are not intended to represent areas requiring independent evaluation for remedial alternatives.

2.1 GEOGRAPHIC SETTING

The boundaries of the 200-BP-5 Groundwater OU encompass an area of approximately 32.6 mi^2 (84.5 km^2). As illustrated in Figure 1-2 and the plate map, the land area overlying the 200-BP-5 Groundwater OU consists of mostly undeveloped land, with clusters of industrial buildings and associated structures mostly located within the fence line of the 200 East Area. The undeveloped land area generally consists of shrub-steppe habitat that contains numerous plant and animal species adapted to the semiarid environment in the region. The developed areas consist of industrial buildings interconnected by roads, railroads, pipelines, and electrical transmission lines. The Columbia River flows through the Hanford Site along the northern boundary of the 200-BP-5 Groundwater OU. Although the river flow in this portion of the Columbia River is not directly impeded by dams, the daily and seasonal water-level fluctuations are controlled by Columbia River dams located upstream from the Hanford Site.

2.1.1 Topography

Surface elevations overlying the 200-BP-5 Groundwater OU range from 320 m (1,050 ft) at the top of Gable Mountain (i.e., a bedrock high) to an average of 120 m (394 ft) at the Columbia River. Besides Gable Mountain, the Central Plateau represents the primary topographic feature overlying the 200-BP-5 Groundwater OU. The Central Plateau occurs as a prominent northeasterly sloping terrace formed during Pleistocene cataclysmic flooding. This terrace, referred to as the Cold Creek flood bar, dominates the topography overlying the south portion of the OU within the boundaries of sub-areas #4, #5, #6, and #7. The margins of this terrace slope to the north overlying sub-areas #2 and #3 and to the northeast overlying sub-area #7.

2.1.2 Climate

The climate at the Hanford Site is classified as mid-latitude, semiarid, or mid-latitude desert, depending on the climatological classification scheme used. Summers are warm and dry with abundant sunshine. Large diurnal temperature variations result from intense solar heating during the day and radiational cooling at night. Daytime high temperatures in June, July, and August periodically exceed 38 °C (100 °F). Winters are cool with occasional precipitation. Outbreaks of cold air associated with modified arctic air masses can reach the area and cause temperatures to drop below -18 °C (0 °F). Overcast skies and fog occur periodically (PNNL-13230, *Hanford Site Groundwater Monitoring for Fiscal Year 1999*).

Weather conditions are monitored and recorded at the Hanford Meteorological Station, which is located near the 200 West Area. Real-time and historical data from the Hanford Meteorological Station can be obtained on the Internet at http://hms.pnl.gov/hms.htm.

Topographic features have a significant impact on the climate of the Hanford Site. The climate of the region is strongly influenced by the Pacific Ocean and the Cascade Mountain Range to the west. The relatively low annual average rainfall of 16.1 cm (6.3 in.) at the Hanford Meteorological Station is caused largely by the rain shadow created by the Cascade Mountain Range.

Prevailing wind directions on the 200 Area Plateau are from the northwest during all months of the year; southwesterly winds occur less frequently. Ranges of daily maximum and minimum temperatures vary from normal maxima of 2 °C (35 °F) in late December to 35 °C (95 °F) in late July. On the average, 52 days during the summer months have maximum temperatures greater than or equal to 32 °C (90 °F), and 12 days have maxima greater than or equal to 38 °C (100 °F). From mid-November through early March, minimum temperatures average less than or are equal to 0 °C (32 °F), with the minima in late December and early January averaging -6 °C (21 °F).

2.1.3 Demography

The Hanford Site is located to the west and south of the Columbia River in Benton County, Washington. The Columbia River forms the border with the adjacent Franklin County, Washington. Estimates for 2005 placed population totals for Benton and Franklin counties at 157,950 and 63,011, respectively,[1] Richland, Washington, is the closest major population center to the 200-BP-5 Groundwater OU. The southern boundary of the 200-BP-5 Groundwater OU is approximately 29 km (18 mi) north of Richland. The 2005 estimates distributed the Tri-Cities (i.e., the cities of Richland, Kennewick, and Pasco) population as follows: Richland at 44,317; Pasco at 46,494; and Kennewick at 60,997. The combined population estimates for the nearby cities of Benton City, Prosser, and West Richland totaled 18,018 in 2005.

2.1.4 Ecology

The Hanford Site is characterized as a shrub-steppe ecosystem. The dominant native plants in undisturbed areas are big sagebrush with an understory of perennial bunchgrasses. Areas that have been impacted by anthropogenic activity associated with Hanford Site operations typically have abundant non-native plant species, such as cheat grass and Russian thistle. Of the 590 species of vascular plants recorded for the Hanford Site, approximately 20 percent of all species are considered non-native.

Approximately 40 species of mammals have been identified on the Hanford Site, including jackrabbits, ground squirrels, bats, elk, and mule deer. The major predator inhabiting the Hanford Site is the coyote, which ranges all across the Site. Bobcats, cougars, and badgers also inhabit the Hanford Site in low numbers. In general, bird species on the Site include a variety of raptors, songbirds, and other species associated with riparian, riverine, and upland habitats.

2.2 GEOLOGY AND HYDROGEOLOGY

This section summarizes the overlying geology as well as the geology and hydrology of the 200-BP-5 Groundwater OU. The geology and hydrology of the Hanford Site have been described in detail in numerous documents, many of which were reviewed during the DQO scoping process. These documents are included by reference in WMP-28945. Hydrogeologic descriptions in this work plan principally follow the recent works referenced below:

- PNNL-12261, *Revised Hydrogeology for the Suprabasalt Upper Aquifer System, 200 East Area and Vicinity, Hanford Site Washington*
- RPP-23748, *Geology, Hydrogeology, Geochemistry, and Mineralogy Data Package for the Single-Shell Tank Waste Management Areas at the Hanford Site*
- Lindsey, 1996, *The Miocene to Pliocene Ringold Formation and Associated Deposits of the Ancestral Columbia River System, South-Central Washington and North-Central Oregon.*

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[1] Census information was obtained from the U.S. Census Bureau at www.census.gov.

2.2.1 General Geology

A description of the general geologic structure and the major stratigraphic units found in the 200-BP-5 Groundwater OU is listed in the following subsections chronologically, from oldest to most recent. The descriptions of bedrock unit structure and stratigraphic units overlying the bedrock follow the interpretation presented in RPP-23748. Stratigraphic facies descriptions, as summarized in RPP-23748 and Lindsey, 1996, are used in this report.

2.2.1.1 Structural Geology

Figure 2-2 illustrates the locations of various mapped structural features, including anticlines, synclines, and faults, as well as geomorphic features. These features influence the occurrence and movement of groundwater and associated groundwater contamination.

The Umtanum Ridge anticline is the principal structural feature within the 200-BP-5 Groundwater OU. This anticline is characterized as an asymmetrical, north-vergent to locally overturned anticline with a major thrust to high-angle reverse fault on the north side. Gable Mountain (the most prominent topographic feature overlying the 200-BP-5 Groundwater OU) and Gable Butte (located northwest of the OU boundary) are bedrock surface expressions of the Umtanum Ridge anticline. Gable Mountain and Gable Butte are composed of a series of northwest trending, double-plunging, en echelon anticlines, synclines, and associated faults (RPP-23748). These features are the primary influence on the bedrock structure in sub-areas #2, #3, #7, #8, and #9.

The majority of the 200 East Area, including sub-areas #4, #5, and #6, lies on the northern flank of the Cold Creek syncline. Bedrock in these areas generally is described as dipping gently to the south. The axis of the northwest-trending Cold Creek syncline occurs south of the 200 Areas (Figure 2-2). Sub-areas #2, #3, #7, and #8 generally include areas where bedrock is suspected to have no apparent dip or is dipping in multiple directions.

Figure 2-3 contains a more detailed illustration of the basalt structure (PNNL-12261). The smaller basalt folds close to the 200 East Area trend northwest-southeast and extends above the water table in certain areas, creating barriers to groundwater flow just north of the 200 East Area.

In the northern portion of the 200-BP-5 Groundwater OU, the Wahluke syncline is a major structural feature. The Wahluke syncline is an asymmetric and relatively flat-bottomed structure similar to the Cold Creek syncline (RPP-23748). This feature influences bedrock primarily in the north portion of sub-areas #1 and #9.

The buried May Junction Fault lineament occurs to the east of the 200 East Area in sub-areas #7 and #8. The vertical displacement of this north-south trending normal fault is estimated to be 56.4 m (185 ft). The vertical displacement at the May Junction Fault may have hydrologic implications on the eastern side of the OU. Specifically, vertical displacement has juxtaposed the sediments of the confined Ringold aquifer with sediments of the Hanford unconfined aquifer (PNNL-12261). The May Junction Fault may impede the movement of water in the Rattlesnake Ridge interbed confined aquifer (i.e., the uppermost basalt confined aquifer) system where permeable units are juxtaposed with impermeable units (PNNL-15670, *Hanford Site Groundwater Monitoring for Fiscal Year 2005*).

2.2.1.2 Stratigraphy

The stratigraphy of the 200-BP-5 Groundwater OU consists of unconsolidated sedimentary deposits that overlie the older Columbia River Basalt Group (CRBG) flood basalts and associated sedimentary interbeds. The principal stratigraphic units that are found in the 200-BP-5 Groundwater OU are listed below, in order from oldest to youngest. These units are further depicted in the hydrogeologic column in Figure 2-4:

- Pomona Member basalt (CRBG)
- Rattlesnake Ridge interbed (Ellensburg formation)
- Elephant Mountain Member basalt (CRBG)
- Miocene-Pliocene Ringold Formation sediments
- Post-Ringold/pre-Hanford deposits (Cold Creek unit)
- Pleistocene Hanford formation sediments.

Note that two sedimentary units overly the 200-BP-5 Groundwater OU and are listed below, in order from oldest to youngest. These units also are depicted in the hydrogeologic column in Figure 2-4:

- Post-Ringold/pre-Hanford deposits (Cold Creek unit)
- Holocene surficial deposits (construction fill and eolian deposits).

2.2.1.2.1 Columbia River Basalt Group. The basalt bedrock within and underlying the 200-BP-5 Groundwater OU is the Miocene-age CRBG. Well over 914 m (3,000 ft) of CRBG basalts and interbeds underlie the OU; however, only the two uppermost members of the Saddle Mountain Basalts, the Pomona and the Elephant Mountain Members, and the intervening Rattlesnake Ridge interbed are relevant to this work plan.

The Pomona Member is the older (lower) of the two basalt units and consists of a single basalt flow. It is one of the most extensive of the Saddle Mountain Basalts, with thickness varying from 50 to 60 m (164 to 197 ft).

The Rattlesnake Ridge interbed is a sedimentary unit (part of the Ellensburg Formation) which overlies the Pomona Member and underlies the Elephant Mountain Member basalt. This unit is composed of fine tuffaceous sands, silts, and clays. The Rattlesnake Ridge interbed was deposited by the ancestral Columbia River subsequent to Pomona volcanism and before extrusion of the Elephant Mountain Member (WHC-SD-EN-TI-037, *Summary of the Geology of the 200-BP-1 Operable Unit*). The interbed consists primarily of air-fall and fluvially reworked fine-grained siliciclastic material, as well as micaceous-arkosic sands derived from the Rocky Mountain terrain (RHO-BWI-LD-5, *Geology of Gable Mountain – Gable Butte Area*). The unit generally thickens to the south, with a maximum thickness of over 25 m (82 ft) in the southwest portion of the 200 East Area, and thins to 0 m in the Gable Gap area (sub-area #2) where the interbed has been completely removed by floodwater erosion (RHO-BWI-LD-5). The thickness of the Rattlesnake Ridge interbed at Well 299-E33-12 was logged as 20 m (66 ft) in sub-area #4. At well 699-53-55A in sub-area #3, the Rattlesnake Ridge interbed is partly eroded and is in direct contact with the overlying Hanford formation due to complete erosion of the overlying Elephant Mountain Member basalt (DOE/RL-92-19, *200 East Groundwater Aggregate Area Management Study Report*).

The Elephant Mountain Member is composed of two basalt flows and is the uppermost basalt unit beneath the 200-BP-5 Groundwater OU. In most of the OU, this basalt member is the base of the unconfined aquifer. The Elephant Mountain Member is composed of two basalt flows and has a total thickness of approximately 20 to 25 m (66 to 82 ft) in the 200 East Area. The top surface of the Elephant Mountain Member has a variable elevation due to anticlinal folds, as reported in Reidel and Fecht, 1994, *Geologic Map of the Priest Rapids 1:100,000 Quadrangle, Washington.* Past sub-aerial erosion also has played a role in changing the top surface configuration of the Elephant Mountain Member. Determining the magnitude of basalt erosion is complicated by the secondary anticlines of the Yakima Folds, which are oriented in generally a northwest-southeast direction. This northwest-southeast orientation also corresponds to the flow direction of Pleistocene floodwater flow through the OU. Depth to the top surface of the Elephant Mountain Member ranges from about 70 to 100 m (230 to 320 ft) below ground surface (bgs) in sub-area #4.

2.2.1.2.2 **Ringold Formation.** The late Miocene to mid-Pliocene Ringold Formation is a regionally extensive sedimentary sequence filling the Pasco Basin. The Ringold Formation consists of river channel sand and gravel deposits, along with overbank sand and silt deposits. The Ringold Formation gravels are clast and matrix-supported, pebble to cobble conglomerates with a fine to coarse sand matrix (Lindsey, 1996). Cemented zones within the conglomerates are discontinuous and of variable thickness. Fresh-water lake mud deposits were deposited between the channel deposits. These mud deposits form layers with lower hydraulic conductivity (K_h) than the associated sand and gravel deposits (DOE/RL-95-59, *200-BP-5 Operable Unit Treatability Test Report*). The Ringold Formation thins or is absent in parts of the 200 East Area and areas north to Gable Mountain. Its absence in the Gable Gap area (between Gable Butte and Gable Mountain) is attributed to erosion by the Missoula Floods and/or the ancestral Columbia River (RHO-BWI-LD-5; RHO-RE-ST-12P, *An Assessment of Aquifer Intercommunication in the B Pond-Gable Mountain Pond Area of the Hanford Site*). Reworked Ringold sediments (mainly gravels) are considered part of the overlying unit(s).

Ringold deposits present at the Hanford Site consist of five separate units dominated by fluvial gravels. The gravels are designated in the geologic log from oldest to youngest, as Units A, B/D, C, and E and are separated by fine-grained deposits typical of overbank and lacustrine environments. The lowermost of the fine-grained sequences is designated as the Lower Mud Unit. As shown in Figure 2-4, only gravel Units A and E are present beneath the 200-BP-5 Groundwater OU. The Ringold Formation is absent beneath the north and northeast portions of the 200 East Area (WHC-SD-EN-TI-012, *Geologic Setting of the 200 East Area: An Update*). In sub-areas #3 and 4 and the western half of sub-area #7, little to no Ringold Formation is found above basalt. In sub-area #6, only gravel Unit A is found.

Ringold sediments that were reworked and deposited by fluvial processes before Ice Age flooding are part of the Plio-Pleistocene unit known as "pre-Missoula gravels." Where the reworked Ringold sediments were deposited by Missoula floodwaters, these sediments are considered part of the Hanford formation.

Important units of the Ringold Formation in the OU are as follows (listed oldest to youngest):

- Ringold Unit A gravels
- Ringold Lower Mud Unit
- Ringold Unit E gravels.

Where present in the OU, the Ringold Formation usually only consists of the lowest unit (Unit A). Considerable erosion of Ringold Formation has occurred in portions of the OU, allowing direct contact between Pleistocene sediments and underlying basalt bedrock.

2.2.1.2.3 Lower Gravel-Dominated Hanford H_3/Cold Creek Unit Undifferentiated. Sediments overlying the Ringold Formation in the 200-BP-5 Groundwater OU are referred to as the Cold Creek unit or the Hanford formation lower gravel/Cold Creek unit undifferentiated (RPP-23748). The Cold Creek unit occurs locally and represents sediments deposited between the late Pliocene and early Pleistocene. However, it was not recognized by well-site geologists in many of the newly installed wells at the single-shell tank (SST) farms (PNNL-14538, *Borehole Data Package for RCRA Wells 299-E25-93 and 299-E24-22 at Single-Shell Tank Waste Management Area A-AX, Hanford Site, Washington*; WMP-18472, *Calendar Year 2003 RCRA Groundwater Monitoring Well Summary Report*).

The Cold Creek unit silt facies may occur locally as a thick silt layer in the vicinity of the WMA-B/BX/BY Tank Farm. HNF-5507, *Subsurface Conditions Description of the B-BX-BY Waste Management Area,* recognized a fine-grained eolian/overbank silt up to 10 m (32 ft) thick and a sandy gravel to gravelly sand facies. A sequence of sandy gravel to gravelly sand occurs beneath the silt-dominated facies and above the top of basalt or Ringold Formation. This gravel sequence represents either cataclysmic flood deposits or ancestral Columbia River deposits. Where the silt unit is absent, the gravel sequence is indistinguishable from similar-appearing facies of the overlying Hanford formation H_3 unit described below, and is referred to as the Hanford formation lower gravel/Cold Creek unit undifferentiated (HNF-5507).

2.2.1.2.4 Hanford Formation. The Hanford formation is the result of sediment deposition associated with glaciofluvial sediments deposited by cataclysmic floods from glacial Lake Missoula, pluvial Lake Bonneville, and other ice-margin dammed lakes (PNNL-13024, *RCRA Groundwater Monitoring Plan for Single-Shell Tank Waste Management Area C at the Hanford Site*). The Hanford formation is present throughout the Hanford Site and is up to 73 m (240 ft) thick (RPP-23748). The Hanford formation consists of pebble- to boulder-size gravel, fine- to coarse-grained sand, and silt. These deposits are divided into three facies: (1) gravel-dominated facies, (2) sand-dominated facies, and (3) silt-dominated facies (WHC-SD-EN-TI-012). In the area of the WMA-B/BX/BY Tank Farm, the Hanford formation can be subdivided into a Hanford formation gravel-dominated facies (H_3), a Hanford formation sand-dominated facies (H_2), and a Hanford formation gravel-dominated facies (H_1). The contacts between the three units are marked by significantly higher natural-gamma counts in the sandy unit. These units are described below (listed oldest to youngest):

- Lower gravel-dominated H_3 unit: The Hanford formation H_3 unit is an open-framework gravel to interstratified gravel and sand with local silt and/or clay horizons. The H_3 unit overlies either the basalt bedrock or the Hanford formation/Cold Creek unit/Ringold silt in sub-area #4. It is known to be as thick as 30 m (98 ft) in the northeast portion of the

200 East Area in sub-area #7. There is approximately 20 m (66 ft) relief on the H_3 unit in that localized area (HNF-5507).

- Sand-dominated H_2 unit: The Hanford formation H_2 unit consists of a sand-dominated sequence. The H_2 unit either overlies the Hanford formation/Cold Creek unit/Ringold silt layer or the H_3 sediment. The H_2 unit is predominantly a poorly to well-sorted, medium- to coarse-grained sand with some silt layers (HNF-5507). The upper portion of the H_2 unit is slightly coarser, with occasional matrix-supported pebbles in a coarse sand matrix. With depth, the medium to coarse sand becomes more frequently interstratified with layers of fine- to medium-grained sand. Distinctive is the "salt and pepper" appearance of the sand imparted by the approximately equal concentrations of dark-colored basalt and light-colored quartz and feldspar. The H_2 unit ranges from 30 m (98 ft) in the north to 60 m (197 ft) in the central and southern portions of the WMA-B/BX/BY Tank Farm (HNF-5507). Two thin (<0.15 m [<0.5 ft]), fine-grained silty layers were observed within the Hanford formation H_2 unit in borehole 299-E33-338 (PNNL-14121, *Characterization of Vadose Zone Sediment: RCRA Borehole 299-E33-338 Located Near the B-BX-BY Waste Management Area*).

- Upper gravel-dominated H_1 unit: The upper gravel-dominated H_1 unit consists of mostly sandy gravel to silty sandy gravel, with lesser amounts of gravelly sand. Thin (0.15 m [0.5-ft]) silt layers are locally present within this sequence. The gravels are multi-lithologic but generally contain a high percentage of basalt. The gravel clasts are generally sub-rounded to well rounded, and the finer fraction has been described as mostly coarse to coarse sand with as much as 5 to 7 percent mud. The samples generally display no cementation or obvious sedimentary structure.

2.2.1.2.5 Holocene Deposits. Holocene deposits include eolian (windblown) sands and construction backfills. Locally, up to 10 m (33 ft) of backfill is present at the WMA-B/BX/BY Tank Farm. The backfill is poorly sorted, gravelly sand to sandy gravel (ARH-LD-129, *Geology of the 241-B Tank Farm;* ARH-LD-130, *Geology of the 241-BX Tank Farm*; and ARH-LD-131, *Geology of the 241-BY Tank Farm*) and is derived generally from nearby borrow pits located in the gravel-dominated Hanford formation.

2.2.2 Hydrogeology

This section describes the vadose zone, the suprabasalt aquifer system (including all sedimentary aquifers and aquitards that occur above basalt), and the confined Rattlesnake Ridge interbed aquifer. A discussion of aquifer boundaries, historical changes in water level, aquifer parameters, aquifer recharge and discharge, and flow direction within the 200-BP-5 Groundwater OU is included.

2.2.2.1 Vadose Zone

The vadose zone generally consists of recent construction fill, Holocene eolian deposits, Hanford formation sands and gravels, and, in some places, the underlying Ringold Formation. Soil moisture in the vadose zone affects transport of contaminants to the unconfined aquifer. Soil moisture content generally is greater in layers composed of fine sediments. Moisture content in the vadose zone beneath past-practice liquid effluent disposal facilities and recharge sources associated with Hanford Site operations (e.g., leaking water lines, sanitary drain fields, parking lot and road run-off) remains greater than adjacent areas under ambient natural recharge conditions. Moisture introduced from precipitation is greatest in areas with sparse vegetation, coarse-grained surface sediments, or where surface drainage is concentrated. Overlying the OU, the vadose zone is thickest in the upland areas of the Cold Creek bar (sub-areas #4, #5, #6, and #7). Depth to the water table ranges from less than 0.3 m (1 ft) near the Columbia River to more than 100 m (328 ft) in southern parts of the OU, excluding exposed basalt outcrops such as Gable Mountain. Localized perched water table conditions have been encountered in vadose sediments above the Hanford/Ringold aquifer system in sub-area #4 (in the vicinity of the WMA-B/BX/BY Tank Farm) and a local area of sub-area #9.

2.2.2.2 Unconfined Aquifer

The unconfined aquifer is present in the majority of the 200-BP-5 Groundwater OU, except where truncated by basalt bedrock or low-permeability sediments. The uppermost aquifer within most of the OU generally is unconfined within the sands and gravels that overlie basalt bedrock or a sedimentary aquitard. Those saturated sands and gravels are composed of Hanford formation/Cold Creek unit undifferentiated or Ringold Formation sediments. In some areas, such as north of Gable Gap, the Ringold Lower Mud Unit is present and acts as a bottom for the unconfined aquifer. The gravels of Ringold Unit E are present in some wells north of Gable Gap, in sub-area #1. In that area, the Lower Mud Unit would be the base of the unconfined aquifer, and the unconfined aquifer would include Ringold Unit E gravels, Cold Creek unit gravels, and possibly Hanford formation H_3 deposits. In most parts of sub-areas #2, #3, and #4 where floodwater erosion has occurred, the unconfined aquifer lies directly over basalt bedrock.

Figure 2-5 is a contour map of water table elevation in 2005. Figure 2-6 shows the approximate thickness of the unconfined aquifer. Saturated sediment thicknesses range from 0 m at the margins of the subsurface basalt high near well 699-52-57, to 1 to 5.5 m (3 to 18 ft) in wells south of the BY Cribs in sub-area #4, to thicknesses up to 13.7 m (45 ft) at the 216-B-5 Reverse Well in sub-area #5 (DOE/RL-95-59). The aquifer generally thickens to the south in sub-areas #5 and #6 as a result of the southerly dip direction of the basalt in that area. The aquifer typically is present, but only 0.3 to 3 m (1 to 10 ft) thick, in Hanford formation gravels to the north of the 200 East Area. The aquifer generally is thickest where the basalt is deep and confining layers, such as the Ringold Lower Mud Unit, are absent, such as in sub-areas #5 and #6 (DOE/RL-95-59).

Figures 2-5 and 2-6 illustrate the horizontal extent of the unconfined aquifer. In several areas, the unconfined aquifer is absent due to basalt highs caused by the structural deformation of the basalt flows and where low-permeability sediments occur above the water table (e.g., the Ringold Lower Mud Unit). For instance, the unconfined aquifer is absent due to a basalt high present in the area between the BY Cribs in sub-area #4 and Gable Mountain Pond to the northeast in sub-area #8. The unconfined aquifer also is absent in the area south of Gable Mountain where the Ringold Lower Mud Unit occurs above the water table. As water levels continue to decline, the lateral extent of the unconfined aquifer will be reduced.

2.2.2.3 Ringold Semi-Confined to Confined Aquifer

Where the Ringold Formation is present, semi-confined to confined aquifer conditions can exist. Local semi-confined to confined aquifer conditions can exist when the Ringold Lower Mud Unit overlies the lowermost Ringold Unit A and the Elephant Mountain Member basalt (PNNL-12261). This confined aquifer occurs in some portions of sub-areas #1, #5, #6, #7, #8, and #9. The lateral extent of this aquifer is not currently well defined. Note that the Ringold Unit A also commonly exists as an unconfined aquifer where the Ringold Lower Mud Unit has been eroded.

Rattlesnake Ridge Interbed Confined Aquifer. The uppermost basalt confined aquifer is represented by the Rattlesnake Ridge interbed. Confined aquifer conditions can occur within the more permeable basalt flow bottoms and brecciated flow tops, while the basalt flow interiors typically have extremely low permeability and act as aquitards. Sedimentary interbeds often occur between these basalt units (Domenico and Schwartz, 1990, *Physical and Chemical Hydrogeology*). Together, the three units (i.e., flow bottom, interbed, and flow top) act as a single confined aquifer. The saturated sediments of the Rattlesnake Ridge interbed, together with the flow bottom of the Elephant Mountain Member basalt and the flow top of the Pomona Member basalt, are examples of such a confined aquifer. The Rattlesnake Ridge interbed confined aquifer is fairly continuous across the Site, except where erosion has cut down as deep as the Pomona Member basalt (e.g., in parts of sub-area #2 and possibly sub-area #3).

The areas of basalt erosion in Gable Gap (sub-area #2) and to the southeast (into northern sub-area #3) are significant because they represent locations of potential aquifer intercommunication between the upper sedimentary interbeds of the Ellensburg Formation and the suprabasalt aquifer system. RHO-RE-ST-12P and others have presented evidence for intercommunication between the unconfined aquifer system and groundwater from the Rattlesnake Ridge interbed. In the Gable Gap area, erosion has cut through the Umatilla Member basalt, exposing the Rattlesnake Ridge, Selah, and Cold Creek interbeds of the Ellensburg Formation. Consequently, the interbeds in this area are in hydraulic communication with the suprabasalt aquifer system (DOE/RL-92-19).

In most portions of the 200 East Area, upward vertical hydraulic gradient conditions exist and the Rattlesnake Ridge interbed discharges into the overlying unconfined aquifer where erosional windows are present. A known area of aquifer discharge occurs in sub-areas #2 and #3 where the Elephant Mountain Member basalt is eroded to expose the underlying Rattlesnake Ridge interbed. Downward hydraulic gradients have occurred in the past around the 216-B-3 Pond area, as well as in the area of Gable Mountain Pond (DOE/RL-92-19).

2.2.2.4 Aquifer Boundaries

The suprabasalt aquifer ultimately discharges to the Columbia River, which represents the base level for the unconfined aquifer. For the confined basalt system aquifers (e.g., the Rattlesnake Ridge interbed), the relatively low permeability of the interiors of basalt flows represent essentially no-flow boundaries for vertical migration of groundwater. However, where eroded or faulted, vertical movement of significant amounts of groundwater may occur. For instance, an erosional "window" in the Elephant Mountain Member basalt occurs in the southern portions of sub-area #3, including in the vicinity of well 699-53-55A. Also, several underlying basalt flows are absent where eroded in Gable Gap, which is in the northern portion of sub-area #2. The high-angle fault on the northern side of Gable Gap also may be an area where groundwater can move readily between confined basalt aquifers and the overlying sedimentary aquifer zones.

2.2.2.5 Historical Changes in Water Level

Liquid effluent disposal at ponds, cribs, trenches, and ditches has impacted groundwater flow and elevations since Manhattan Project operations commenced in 1944. Water levels have changed during Hanford Site operations in response to changes in the volume and location of wastewater discharged to the ground. Consequently, the movement of groundwater and its associated constituents also has changed over time. A detailed description of historical groundwater levels is presented in Appendix D of WMP-28945.

The main driving forces related to changing groundwater elevations and flow direction in the 200-BP-5 Groundwater OU were wastewater discharges to the B Pond and Gable Mountain Pond. During the 1950s it was recognized that disposal of large volumes of cooling water from Plutonium-Uranium Extraction (PUREX) to the existing B Pond could mobilize contamination beneath waste sites to the north. Consequently, it was recommended that PUREX cooling water be discharged to a new swamp south of Gable Mountain to deny the contamination access to the channels of high groundwater velocity near the flanks of Gable Mountain (HW-49728, *The Effect of Ground-Water Mounds on the PUREX Operation*). PNL-10817, *Hydrochemistry and Hydrogeologic Conditions Within the Hanford Site Upper Basalt Confined Aquifer System,* found evidence that groundwater mounding associated with past wastewater discharges at B Pond and the Gable Mountain Pond (now decommissioned) locally formed a downward-driving force from the contaminated unconfined aquifer system to the underlying confined Ringold and the Rattlesnake Ridge interbed confined aquifer (uppermost basalt confined aquifer) systems.

During periods of operation, the significant discharges at the B Pond resulted in the creation of a radial flow pattern that locally reversed the natural flow of groundwater in the 200 East Area from its previous west-to-east direction toward the Columbia River to a more east-to-west direction (RHO-ST-42, *Hydrology of the Separations Area*). The reversal of groundwater flow altered the migration of groundwater out of the 200 Area Plateau. With the discontinued use of the Gable Mountain Pond, increased groundwater flow to the northwest through the Gable Gap area was evident by contaminant transport of mobile contaminants such as tritium, Tc-99, and nitrate. In recent years, this mound has nearly disappeared and flow to the northwest has been lessened. Since wastewater discharge from the 200 East Area operations has been reduced, the hydraulic head in the unconfined aquifer has been declining at a higher rate than the hydraulic head in the confined Ringold and the Rattlesnake Ridge interbed confined aquifer (PNNL-12261).

2.2.2.6 Aquifer and Aquitard Parameters

Aquifer hydraulic properties (including K_h, specific yield, storage coefficient, and effective porosity) are needed to estimate groundwater and contaminant travel times. Contaminant travel times also are a function of the geochemical properties of the aquifers and aquitards. Hydraulic data for the unconfined aquifer are derived mainly from well pumping and slug tests and, in a few cases, laboratory tests of sediment samples. Results are available from published and unpublished investigations conducted over the past 50 years. A summary of available data for the Hanford/Ringold aquifer system is provided in DOE/RW-0164, *Consultation Draft: Site Characterization Plan, Reference Repository Location, Hanford Site, Washington*, and an updated summary, together with an evaluation of selected pumping test analyses, is provided in PNL-8337, *Summary and Evaluation of Available Hydraulic Property Data for the Hanford Site Unconfined Aquifer System.*

Table 2-1 lists the current estimates of hydraulic conductivities for the various hydrogeologic units. Often the lower gravel unit is the only part of the Hanford formation that is saturated. Ringold Unit E is often included with the Hanford formation, because the unconfined aquifer has no significant aquitard separating these units in the portions of the OU scoured by floodwaters.

The estimated distribution of unconfined aquifer transmissivity has been mapped in PNNL-13080, *Hanford Site Groundwater Monitoring: Setting, Sources and Methods*. This distribution was determined from the results of aquifer tests combined with a flow model calibration procedure in PNNL-11810, *Results of Phase I Groundwater Quality Assessment for Single-Shell Tank Waste Management Area S-SX at the Hanford Site*. The mapped distribution of transmissivity shows a zone of high transmissivity (20,000 to 125,000 m^2/day) that extends from northwest to southeast across more than half of the 200-BP-5 Groundwater OU. This zone of high transmissivity generally corresponds with the presumed main flow channels of the glacial floods. Where they are found below the water table, the Hanford formation gravels make up the most conductive zones of the Hanford/Ringold aquifer system. The K_h of these sediments generally is 10 to 100 times greater than the K_h of Ringold Formation gravels.

Specific yield values calculated from several multiple well tests range from 0.02 to 0.38 and have a mean of 0.15 (PNL-10886, *Development of a Three-Dimensional Ground-Water Model of the Hanford Site Unconfined Aquifer System: FY 1995 Status Report*). For a relatively permeable unconfined aquifer, specific yield is approximately equal to effective porosity, which is an important parameter used to calculate contaminant travel times (Domenico and Schwartz, 1990). Aquifer-specific yield, which is a measure of the volume of water released from aquifer storage in response to a change in the water-table elevation, is more difficult to measure than K_h and generally requires relatively long-duration aquifer-pumping tests with observation wells (PNL-8539, *Selected Hydraulic Test Analysis Techniques for Constant-Rate Discharge Tests*) or slug tests with observation wells (PNL-10835, *Comparison of Constant-Rate Pumping Test and Slug Interference Test Results at the B-Pond Multi-Level Test Facility*; PNL-10817). Even for these tests, the calculated specific yield is subject to errors that result from non-ideal test conditions, such as aquifer heterogeneity, anisotropy, and partially penetrating wells (PNL-8539). Because of purgewater management constraints, few high-yield pumping tests have been performed at the Hanford Site.

2.2.2.7 Aquifer Recharge and Discharge

Natural recharge to the Hanford/Ringold aquifer system occurs because of infiltration of run-off from elevated regions along the western boundary of the Hanford Site. Upwelling of groundwater that originates from the regional basalt-confined aquifer system and precipitation naturally recharge the unconfined and Ringold confined aquifer systems. Recharge from precipitation is highly variable, both spatially and temporally. It ranges from near zero to greater than 100 mm/yr, depending on climate, vegetation, and soil texture (Gee et al., 1992, "Variations in Recharge at the Hanford Site"; PNL-10285, *Estimated Recharge Rates at the Hanford Site*). Recharge from precipitation is the highest in coarse-textured soil with little or no vegetation.

Some artificial recharge to the unconfined aquifer currently occurs as a result of irrigation waters, which are applied in distant agricultural areas of the upper Cold Creek Valley west of the Hanford Site, as well as in areas south of the Hanford Site. The only site actively releasing liquid effluent to the ground in this OU is the Treated Effluent Disposal Facility in sub-area #7.

Since the start of Hanford Site operations in the early-1940s, artificial recharge from wastewater disposal facilities has greatly exceeded the estimated recharge from natural sources and resulted in the formation of groundwater mounds beneath major wastewater disposal facilities, such as the B Ponds and Gable Mountain Pond. However, beginning in 1988, production activities on the Hanford Site closed and, by 1995, all major liquid effluent disposals to the ground had ceased. Subsequently, the water table elevation has declined in the 200 Areas.

In most parts of the 200-BP-5 Groundwater OU, upward vertical hydraulic gradient conditions exist and the Rattlesnake Ridge interbed discharges into the overlying unconfined aquifer where erosional windows are present. The locations of groundwater discharge for the confined basalt system are influenced by geologic structures that increase the vertical permeability of the confining basalt layers. Additional information on the Rattlesnake Ridge interbed confined aquifer (uppermost basalt confined aquifer) system is available in PNL-10158, *Summary and Evaluation of Hydraulic Property Data Available for the Hanford Site Upper Basalt Confined Aquifer System*; DOE/RW-0164; and PNL-10817.

2.2.2.8 Groundwater Flow

Groundwater in the uppermost basalt confined aquifer generally flows from elevated regions at the edge of the Pasco Basin toward the Columbia River (PNL-10817). Figure 2-5 contains a water table contour map, which illustrates that groundwater in the unconfined aquifer is flowing toward and discharging to the Columbia River. Some local perturbation to this generalization occurs where artificial recharge mounds are present or during times of high river stage. Two major flow directions in the unconfined aquifer have been described by previous studies. There is a northerly flow component through Gable Gap and a southeasterly flow component toward the 200-PO-1 Groundwater OU. The groundwater flow north of Gable Mountain is not well-defined but may discharge in the vicinity of the 100-BC-5 and 100-KR-4 Groundwater OUs. The southeasterly flow is a longer flowpath, heading southeast of Gable Mountain and eventually discharging to the Columbia River. The location of the groundwater divide, which separates these two diverging flow paths, is not known at this time. As groundwater levels decline, the groundwater divide will shift northward and the southeasterly component of groundwater flow will become more dominant. As suggested by Figure 2-5, some groundwater from the 200 West Area may flow through Gable Gap.

2.3 OPERATIONAL AND DISPOSAL HISTORY BY SUB-AREA

The 200-BP-5 Groundwater OU underlies a large geographic area of the Hanford Site and has been potentially impacted from planned and unplanned releases (UPR) from waste sites, facilities, and ancillary equipment. This section includes a summary of the historical operations, disposal practices, and unique characteristics and data needs associated with each sub-area overlying the 200-BP-5 Groundwater OU. Figure 2-1 provides an overall map of the sub-areas.

2.3.1 Sub-Area #1 – North of Gable Gap to Columbia River

Sub-area #1 is depicted in Figure 2-7. Its northern boundary is the Columbia River, which is the only major surface-water feature potentially impacted by contaminated groundwater within the 200-BP-5 Groundwater OU. The southern boundary of the sub-area is in the vicinity of the topographic feature between Gable Mountain and Gable Butte, which is known as Gable Gap. The northern portion of sub-area #1 is bound to the east by the 100-KR-4 Groundwater OU and to the west by the 100-BC-5 Groundwater OU.

Sub-area #1 consists of essentially undeveloped land, with the exception of intersecting transportation routes. There are no known potential direct sources of groundwater contamination; however, indirect impacts are possible due to the bordering groundwater OUs (i.e., 100-BC-5 and 100-KR-4). There are no previous operations, disposal practices, or WMAs associated with sub-area #1. The potential for liquid discharges to the unconfined aquifer is minimal.

2.3.2 Sub-Area #2 – West Lake and Gable Gap

Sub-area #2 is depicted in Figure 2-8. The northern boundary of this sub-area lies in the vicinity of the Gable Gap area, and the southern boundary is approximately 0.64 km (0.4 mi) south of West Lake.

Sub-area #2 consists of essentially undeveloped land, with the exception of intersecting transportation routes. The major surface feature of sub-area #2 is West Lake. West Lake surface levels were directly impacted when large volumes of water were discharged to Gable Mountain Pond (developed in 1957 and active until 1984). When Gable Mountain Pond was taken out of service, West Lake once again became ephemeral, as it is currently. The water-surface level of West Lake depends on run-off from recent precipitation events, which occur seasonally.

Historical disposal practices in sub-area #2 appear to have been limited to a test crib near West Lake that was built in 1959 for a field experiment to predict crib capacity and crib waste retention. A calcium nitrate solution spiked with Sr-85 was placed in the 0.37 m^2 (4 ft^2) crib. At present, potential for liquid discharges to the unconfined aquifer is minimal.

2.3.3 Sub-Area #3 – South Gable Gap

Sub-area #3 is depicted in Figure 2-9. The northern boundary of this sub-area lies approximately 0.64 km (0.4 mi) south of West Lake, and the southern boundary occurs approximately 244 m (800 ft) north of the 200 East Area fence line. Sub-area #3 is bordered to the west by the 200-BP-5 Groundwater OU boundary and to the east by sub-areas #7 and #8.

The 200 North aggregate area overlaps the western portion of sub-area #3. This site was the location of three ponds (216-N-1, 216-N-4, and 216-N-6) and four trenches (216-N-2, 216-N-3, 216-N-5, and 216-N-7) in the 200 North aggregate area, located in sub-area #3. The ponds each received a total of approximately 946 million L (250 million gal) from 1944 to 1952 and may have contributed minor amounts of radionuclides to the unconfined aquifer (DOE/RL-92-19). Each of the trenches received a total of 7.57 million L (2 million gal) in June 1952.

Other than the 200 North Area facilities described above, sub-area #3 consists of essentially undeveloped land, with the exception of intersecting transportation routes. There are no other known potential direct sources of groundwater contamination, previous operations, disposal practices, or WMAs associated with sub-area #3. The potential for future liquid effluent discharges to the unconfined aquifer is minimal.

2.3.4 Sub-Area #4 – BY Cribs, BX Trenches, and Waste Management Area B/BX/BY

The boundary of sub-area #4 is depicted in Figure 2-10. The northern boundary occurs approximately 244 m (800 ft) north of the 200 East Area's northwest fence line. The southern margin coincides with the southern boundary of LLWMA-1 and extends to the east and south of the WMA-B/BX/BY Tank Farm complex. This sub-area has facilities including the WMA-B/BX/BY Tank Farm and LLWMA-1 that have groundwater-monitoring requirements under RCRA and AEA. RPP-10098, *Field Investigation Report for Waste Management Area B-BX-BY*, presents the assessment of information available about the nature and extent of past releases within the tank farms located in the WMA.

The B Tank Farm was built from 1943 to 1944. From 1946 through 1949, the BX and BY Tank Farms and Cribs, notably the 216-B-8 Crib, were constructed to handle large volumes of generated waste. Each tank farm contains 12 tanks, except for the B Tank Farm, which contains 16 tanks.

The B Plant was constructed in 1944 and brought on-line in 1945 to extract plutonium from fuel rods using the bismuth-phosphate fuel separation process. Plutonium separation began with the dissolution of the aluminum-jacketed fuel rods in a sodium-hydroxide solution, to which sodium nitrate was added to avoid the formation of too much hydrogen. The resulting sodium aluminate-sodium nitrate solution was a component of the first-cycle waste stream sent to underground tanks. The remaining uranium metal slugs were rinsed in water and dissolved in a mixture of 70 percent nitric acid and pure sulfuric acid. The sulfuric acid was used to complex dissolved uranium and increase its solubility. Sodium nitrite and bismuth nitrate-nitric acid and phosphoric acid were added at various stages to the dissolver/precipitate solution, called metal waste solution in the process scheme, to separate impurities associated with uranium metal and the plutonium. Eventually bismuth-phosphate precipitate containing plutonium product was separated by centrifugation and washing. The remaining solution, called metal waste solution, contained most of the uranium and fission products not prone to precipitation as phosphates. The metal waste solution was first neutralized with 50 percent sodium hydroxide solution, then treated with 30 percent sodium carbonate solution, and finally sent to the underground tanks in tank farms.

The product precipitate was again treated to remove additional fission products from the plutonium-product precipitate using the bismuth-phosphate precipitation steps. This first plutonium purification step was referred to as the first-cycle process, which attempted to reduce the fission activity to 3 Ci, or approximately 0.001 percent of the total fission product. The liquid waste from this treatment was combined with coating removal waste. The entire plutonium purification process was repeated a second time and was referred to as the second decontamination cycle waste. These liquid waste streams from the second decontamination cycle were kept separate and neutralized, then sent to the B/BX/BY Tank Farms.

In 1945, the B Tank Farm began receiving bismuth-phosphate waste from the B Plant. Because of limited tank space, intentional discharge of lower activity bismuth-phosphate waste to the soil column began in 1945 in the 216-B-5 and 216-B-6 Reverse Wells and in the 216-B-8 Crib (HW-43121, *Tabulation of Radioactive Liquid Waste Disposal Facilities*). In late 1946, the 216-B-7A Crib also was added for disposal of lower activity bismuth-phosphate waste. From 1948 through 1951, the 216-B-8 Crib was the primary discharge facility, receiving approximately 27 million L (7.13 million gal) of waste. To improve liquid reduction, Evaporator 242-B was built in 1951 and began shipping condensate to the 216-B-11A and 216-B-11B Reverse Wells.

Substantial amounts of uranium were present in the B/BX/BY Tanks from the initial bismuth-phosphate process waste. Beginning in 1952, the waste was sluiced from the tanks and sent to the U Plant where uranium was extracted. A portion of the liquid waste generated from the uranium removal process was ultimately disposed in the BY Cribs and BX Trench 216-B-42 in 1954 and 1955. The remaining liquid waste was sent to the BC Cribs and T Cribs outside of the 200-BP-5 Groundwater OU. The eight BY Cribs received approximately 34 million L (9 million gal) of the liquid waste, and the BX Trench 216-B-42 received 1.5 million L (400,000 gal).

Following completion of the uranium recovery program, an in-tank solidification process was initiated to remove excess liquid from the tanks by evaporating the liquid and sending the condensate to the 216-B-50 and 216-B-57 Cribs (ISO-986, *B-Plant Phase III Flowsheets*). Between 1965 and 1974, the 216-B-50 Crib received 59 million L (15.6 million gal) of condensate, and the 216-B-57 Crib received 84 million L (22.2 million gal) of condensate.

From 1967 to 1979, the B Plant was reactivated as an isotope recovery and storage facility. The B Plant high-level waste streams and low-activity waste streams that resulted from this phase of B Plant operations were routed to tanks in the B/BX/BY Tank Farms. Some of the B Plant isotope recovery programs used organic complexing agents extensively to facilitate specific radionuclide separations. Many of the organic complexing agents ended up in the high-level waste stream coming from the B Plant. All of the SSTs were removed from service in the late 1970s through 1980.

The cribs and trenches located within sub-area #4 that are known or suspected sources of groundwater contamination include the 216-B-7A and 216-B-7B Cribs, 216-B-8 Crib, 216-B-43 through 216-B-50 Cribs, and the 216-B-57 Crib. The 216-B-7A and 216-B-7B Cribs operated from 1946 to 1967 and received a total volume of 43.5 million L (11.5 million gal) of wastewater. From October 1946 to August 1948, these cribs received 22.2 million L (5.86 million gal) of 221-B Building (B Plant) waste; 224-B Concentration Facility waste; and cell drainage and low-salt, alkaline, radioactive liquid that was overflow from SST 241-B-201. After August 1948, the cribs received cell 5-6 drainage and equipment cleanout liquid waste directly from the 224-B Building until October 1961. From October 1961 to May 1967, decontamination construction waste from the B Plant was disposed in the cribs.

The 216-B-8 Crib and Tile Field received 27.3 million L (7.2 million gal) of lower activity bismuth-phosphate waste between April 1945 and December 1951. From 1945 through July 1951, the crib received second-cycle supernatant waste from the B Plant. For the last 6 months of 1951, the crib received cell drainage and other liquid waste from tank 5-6 in the B Plant.

The 216-B-43 through 216-B-49 Cribs each received scavenged tributyl phosphate (TBP) supernatant waste from the 221-U Building and the 241-BY Tank Farm. The TBP acid waste from the U Plant was made alkaline for transport and sent to the BY Tank Farm, where it was treated with potassium ferrocyanide as a cesium scavenger. The supernatant was discharged to the cribs after allowing the cesium to precipitate.

The 216-B-50 Crib received 54.9 million L (14.5 million gal) of waste storage tank, intermediate-level process condensate from in-tank solidification unit #1 in the BY Tank Farm, similar to the 216-B-57 Crib. The 216-B-57 Crib operated from February 1968 to June 1973 and received 84.4 million L (22.3 million gal) of waste storage condensate from in-tank solidification unit #2 of the BY Tank Farm. The condensate waste was reduction-oxidation (REDOX) and PUREX process fractionalization waste originally generated by the REDOX and PUREX processes.

The 216-B-35 through 216-B-41 Trenches received a combined volume of 14.3 million L (3.79 million gal) of first-cycle, high-salt, neutral/basic supernatant waste from the B Plant.

The 216-B-42 Trench received 1.5 million L (400,000 gal) of scavenged TBP waste from the 221-U Building and the BY Tank Farm.

The 216-B-11A and 216-B-11B Reverse Wells were put into service in December 1951 and were removed from service in December 1954. Throughout their operational lifetime, they received 29.5 million L (7.8 million gal) of processed condensate liquid waste from the 242-B Evaporator. These wells are essentially dry wells and consist of two 1.2 m (4-ft)-diameter by 9.1 m (30-ft)-long, corrugated-steel culverts buried vertically, 3 m (10 ft) bgs. The culverts are perforated on 15.2 cm (6-in.) centers at 30.5 cm (12-in.) vertical intervals along all but the bottom 15.2 cm (6 in.) of length of the culvert. The culverts are placed in a 2.4 m (8-ft)-diameter excavation that is filled with 7.6 cm (3-in.)-diameter rock. The waste was low-salt, neutral to basic and contained transuranic waste.

LLWMA-1 also is located in sub-area #4. LLWMA-1 contains the solid waste 218-E-10 Burial Ground. The 218-E-10 Burial Ground is approximately 36.1 ha (89.2 ac) in size and began receiving waste in 1960 (PNNL-14859, *Interim Status Groundwater Monitoring Plan for Low-Level Waste Management Areas 1 and 4, RCRA Facilities, Hanford, Washington*). Examples of waste placed in this burial ground include failed equipment, rags, paper, rubber gloves, disposable supplies, and broken tools.

2.3.5 Sub-Area #5 – B Plant and Nearby Cribs

The boundary of sub-area #5 is shown on the plate map and in Figure 2-11. The northern boundary coincides with the southern boundary of LLWMA-1 and is just south of the WMA-B/BX/BY Tank Farm complex. The southern margin of the sub-area coincides with the 200-PO-1 Groundwater OU boundary approximately through the north-south mid-point of the 200 East Area. Several small groundwater plumes appear to originate in this sub-area. A summary of the waste-site operations and disposal history of the potential plume sources is discussed below.

The B Plant aggregate area buildings that were the primary generators of waste include the 221-B Building (B Plant), the 224-B Concentration Facility, the 222-B Laboratory, and the 225-B Building (Waste Encapsulation and Storage Facility).

The 224-B Concentration Facility was used to remove additional fission products and product, as described in the previous section. This process was completed with various acid/base reactions to separate the unwanted fission products. The waste streams were neutralized and considered safe to dispose to the ground because they contained less than 0.001 percent of the total fission product originally present in the irradiated uranium metal slugs.

The 222-B Laboratory was used from 1945 until 1952 for small-scale experiments in support of B Plant bismuth-phosphate fuel processing. The facility disposed liquid waste to the 216-B-6 Reverse Well and the 216-B-10A Crib.

The 225-B Building was constructed in 1974 to house the processing systems needed to encapsulate recovered cesium and strontium from the isotope recovery programs and to safely store the encapsulated material.

The B Plant aggregate area contains a variety of facilities that were involved in waste generation and TSD. High-level wastes were stored in underground tanks. Lower activity radiologically contaminated processing wastes were discharged to the soil column through cribs, trenches, and other facilities.

The known and suspected sources of groundwater contamination within sub-area #5 are discussed below.

- The 216-B-12 Crib received approximately 520.1 million L (137.4 million gal) of liquid effluent. From 1952 to 1957, the crib received process condensate from the uranium recovery program at the 221-U and 224-U Buildings, as well as process condensate from the B Plant, and was inactive from 1958 to 1967. From 1967 to 1973, the crib received B Plant process condensate from the isotope separations process. The waste is low-salt and neutral/basic. Inorganics disposed in the crib include ammonium nitrate.
- The 216-B-62 Crib was active from 1973 to 1991. The crib was built to replace the 216-B-12 Crib and received approximately 282 million L (74.5 million gal) of low-level process steam condensate from the B Plant during its operational lifetime.
- The 216-B-5 Reverse Well received liquid from the 224-B Concentration Facility and B Plant as the overflow waste from the 241-B-361 Settling Tank from April 1945 through September 1946. Between September 1946 and October 1947, cell drainage and other liquid waste from the B Plant were injected into the well. Approximately 30.7 million L (8.1 million gal) were discharged at the 216-B-5 Reverse Well directly to the groundwater.
- The 216-B-6 Reverse Well operated from April 1945 to November 1949, receiving approximately 6.1 million L (1.6 million gal) of liquid waste from the 222-B Laboratory. The waste was acidic, containing nitric and sulfuric acid and transuranic fission products.
- The 216-B-4 Reverse Well waste site is located south of the 221-B Building and was the source of 291-B Stack drainage and 292-B Building floor drainage from 1945 to 1949. The reverse well extended 34 m (112 ft) bgs. The derived waste inventory indicates that this waste site did not receive significant radionuclide concentrations. No existing groundwater wells are associated with this waste site.

2.3.6 Sub-Area #6 – Semiworks and Waste Management Area C

The boundary of sub-area #6 is shown on the plate map and in Figure 2-12. Sub-area #6 generally encompasses the WMA-C Tank Farm and the Hot Semiworks Plant area. The area borders the 200-PO-1 Groundwater OU to the south and extends to the eastern 200-BP-5 Groundwater OU boundary. This sub-area includes WMA-C, which has groundwater-monitoring requirements under RCRA and AEA.

The WMA-C Tank Farm is located in the east central portion of the 200 East Area. The C Tank Farm was built from 1943 to 1944. Beginning in 1946, the tank farm received bismuth process waste from the B Plant. All 200-series tanks, along with SSTs C-101 to C-106, received metal waste and SSTs C-107 through C-112 received first-cycle waste. By the end of 1948, all tanks in the tank farm were filled with waste from the bismuth-phosphate process.

To free up tank space, in 1952 first-cycle waste was transferred to the 242-B Evaporator. In 1952 and 1953, metal wastes were sluiced from the WMA-C Tank Farm and sent to the U Plant for uranium extraction. Ancillary equipment involved in the metal waste transfer included the 244-CR Vault and the 241-CR-151, 241-CR-152, and 241-CR-153 Diversion Boxes.

Subsequently, TBP waste, a byproduct of the uranium recovery process, was returned to the C Tank Farm. Beginning in May 1955 and through December 1957, the 244-CR Vault was modified to scavenge TBP waste (i.e., to separate Cs-137 from the supernatant by precipitation). Waste from SSTs C-107 through C-112 was used as feed for the 244-CR Vault. The scavenged slurry was put back into SSTs 241-C-109 and 241-C-112 to settle, and the resultant supernatant was discharged to the BC Cribs. The vault was used later as a receiving station, and operations ceased in 1988.

Several other waste streams were routed to one or more tanks in the WMA-C Tank Farm. These include S Plant ion-exchange (IX) wastes, N Reactor complex waste, evaporator-bottom concentrate from the B and BX Tank Farms, S Plant supernatant, process development wastes from Hot Semiworks (C Plant), low-level and metal waste from the B Tank Farm, and Hanford Site laboratory operations waste (DOE/RL-92-04, *PUREX Plant Source Aggregate Area Management Study Report*).

Fourteen UPRs have occurred within or adjacent to the WMA-C Tank Farm. Some of the UPRs are surface "spot" contamination that would not impact the groundwater in the 200-BP-5 Groundwater OU. A brief description of the UPRs that have potentially contributed to groundwater contaminant plumes is presented below. The descriptions are summarized from *Waste Information Data System* (WIDS) database general summary reports and represent the best information available on the nature and extent of releases. Substantial uncertainty exists regarding the volume and content of the UPRs from components within the WMA-C Tank Farm.

- UPR-200-E-136 was a release of 64,345 to 90,840 L (17,000 to 24,000 gal) of waste from SST C-101. A total of 2,000 Ci were released between 1946 and 1970 (DOE/RL-92-04).

- UPR-200-E-137 occurred when water entered SST C-203, migrated through the salt cake, and either became entrained in the salt cake or leaked out of the tank. The leak was 1,514 L (400 gal) of PUREX Plant high-level waste.

- UPR UN-200-E-81 is located northeast of the 244-CR Vault, near the 241-CR-151 Diversion Box. It occurred as a result of a leak in an underground transfer pipeline in October 1969. The waste leaked from the pipeline consisted of PUREX coating waste.

- UPR UN-200-E-82 occurred in December 1969. The source was determined to be the feed line running between SST C-105 and the 221-B Building. The leak was discovered near the 241-C-152 Diversion Box. The liquid release flowed from the vicinity of the 241-C-152 Diversion Box to the northeast, downgrade, until it pooled into an area, measuring approximately 0.46 m^2 (5 ft^2) outside of the WMA-C Tank Farm fence. The leak volume is unknown.

- UPR UN-200-E-86 was a spill that resulted from a leak in a pipeline used to transfer waste from the 244-AR Vault to the WMA-C Tank Farm. The depth of the leaking pipeline was approximately 2 m (8 ft) bgs. The release occurred in March 1971 near the west corner of the WMA-C Tank Farm, outside of the fence. The spill consisted of 25,000 Ci of Cs-137. The soils surrounding the pipeline were sampled, and it was determined that the contamination had not penetrated below 6 m (20 ft). The contamination plume volume was estimated at 37 m^3 (1,300 ft^3).

- UPR UN-200-E-100 was a surface spill of unknown volume and constituents that occurred in 1986. It is located approximately 60 m (197 ft) south and east of the WMA-C Tank Farm and surrounds the 244-A Lift Station.

- UPR UN-200-E-107 was a surface spill located north of the 244-CR Vault, inside of the WMA-C Tank Farm. DOE/RL-92-04 indicates that a spill occurred on November 26, 1952, when a pump discharged liquid to the ground surface during a pump installation. The spilled waste was TBP waste from the 221-U Building. The volume of the spill and any cleanup measures were not documented.

The Semiworks aggregate area was composed of two primary facilities: the 201-C Process Building and the Critical Mass Laboratory (209-E Building). The 201-C Process Building was constructed in 1949 as a pilot plant for reprocessing reactor fuel using first the REDOX (S Plant) chemical process and then the PUREX chemical process. In 1961, it was converted to recover strontium from fission product waste. This facility operated until 1967 and remained in safe-storage mode until decommissioning began in 1983.

Criticality experiments and research were conducted by Pacific National Laboratory at the 209-E Building from 1960 to 1987.

The Semiworks aggregate area contains a variety of facilities that were involved in waste generation and TSD. High-level wastes were stored in underground tanks. Radiologically contaminated processing wastes were discharged to the soil column through cribs, trenches, and other facilities. The Semiworks aggregate area contains seven cribs, a reverse well, one ditch, one pond, and a burial site. The burial site, the 218-C-9 Burial Ground, received 2,265 m^3 (80,000 ft^3) of rubble from decommissioning of the 201-C Process Building and should not directly contribute contamination to the groundwater in the 200-BP-5 Groundwater OU.

The cribs and french drains in sub-area #6 received nearly 30 million L (8 million gal) of low-level waste for disposal. Two of the cribs received more than 90 percent of the waste. The first, the 216-C-1 Crib, began operating in 1953 and was retired in June 1957 after receiving approximately 23.5 million L (6.2 million gal) of liquid waste. The crib received REDOX and PUREX high-salt waste, process condensate from the 201-C Process Building, and material described as "cold-run" waste from the REDOX and PUREX processes (DOE/RL-92-18, *Semiworks Plant Source Aggregate Area Management Study Report*). The second, the 216-C-3 Crib, received 4.9 million L (1.3 million gal) of liquid acidic REDOX process waste from the 201-C Process Building, 215-C Gas Preparation Building, and 271-C Aqueous Makeup and Control Building between 1953 and 1954.

Reverse wells are encased drill holes with the lower end of the casing perforated or open to allow liquid to seep into the vadose zone at depths greater than that for the cribs and french drains. The reverse well identified at the Semiworks aggregate area is 216-C-2 and is an Ecology-registered underground injection well. The 216-C-2 Reverse Well received condensate from the 291-C Stack and seal-water drainage from the stack ventilation filter between 1953 and 1988.

The liquid waste is characterized as low-salt and neutral/basic, and the volume of waste is unknown.

The 216-C-9 Pond began operation in 1953 as a receiving site for process cooling water from the Semiworks facilities. In 1960, the site began receiving miscellaneous wastewater from the Critical Mass Laboratory, in addition to the process cooling water. From 1969 to 1985, the pond received miscellaneous wastewater from the 201-C Process Building and the Critical Mass Laboratory. The Critical Mass Laboratory miscellaneous wastewater stream consisted mostly of effluent from equipment and floor drains in the utility and change rooms. One source of waste cooling water came from the mixing room and potentially was contaminated with radionuclides. During its operation history, the 216-C-9 Pond received liquids with cesium, ruthenium, strontium, plutonium, and alpha and beta contamination. The pond received a total waste volume of more than 1 billion L (272 million gal) of liquid waste while it was in service.

There are four documented UPRs identified with the Semiworks aggregate area. The UPRs each involve surface contamination and would not impact groundwater. Two other releases were identified, which originated from failed Teflon[1] gaskets in flanges in the 241-C Waste Line running from the 201-C Process Building to the 241-C Tank Farm. Piping was installed to bypass the leaking sections, but waste inventory or volume estimates for the releases are not available.

2.3.7 Sub-Area #7 – B Pond Vicinity

Sub-area #7 is depicted on the plate map and in Figure 2-13. Sub-area #7 generally encompasses the northeast quadrant of the 200 East Area and extends easterly along the southeastern boundary of the 200-BP-5 Groundwater OU. The southern boundary of sub-area #7 borders sub-area #6's northern boundary, roughly halfway between LLWMA-2 and the WMA-C Tank Farm. Sub-areas #3, #4, and #5 are directly west and sub-area #8 is directly north. This sub-area has facilities that have groundwater-monitoring requirements under RCRA and AEA, which include LLWMA-2, the 216-B-63 Trench, LERF, and portions of the B Pond.

The LLWMA-2 contains a solid waste burial ground (218-E-12B). The 218-E-12B Burial Ground includes Trench 94, which contains defueled naval reactor compartments. These reactor compartments contain Washington State-only regulated lead shielding that is encased in steel.

The LERF consists of three RCRA-compliant surface impoundments for temporary storage of process condensate from the 242-A Evaporator and other sources. The LERF provides equalization of the flow and pH control of the feed to the Effluent Treatment Facility.

The 216-B-63 Trench is an open, unlined, earthen trench, approximately 1.2 m (4 ft) wide at the bottom, 427 m (1,400 ft) long, and 3 m (10 ft) deep that received wastewater containing hazardous waste and radioactive materials from the B Plant, located in the 200 East Area. Liquid effluent discharge to the 216-B-63 Trench began in March 1970 and ceased in February 1992.

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[1] Teflon is a trademark of E.I. du Pont de Nemours and Company, Wilmington, Delaware.

The B Pond consisted of a main pond and three expansion ponds (3A, 3B, and 3C). The ponds were constructed for wastewater disposal purposes. The main pond began receiving effluent in 1945, and the three expansion ponds were placed into service in 1983, 1984, and 1985, respectively, as replacements for Gable Mountain Pond. Discharge volumes to the B Pond were at a maximum during 1988. Beginning in April 1994, discharges to the main pond and the 3A Expansion Pond ceased, and all effluents were rerouted to the 3C Expansion Pond via a pipeline. In June 1995, portions of the effluent stream were rerouted to the 200 Areas Treated Effluent Disposal Facility located in the 200-PO-1 Groundwater OU. The remaining streams were diverted from the 3C Expansion Pond to the Treated Effluent Disposal Facility in August 1997, thus ending all operation of the B Pond. The 3C Expansion Pond still is maintained as an overflow contingency facility for the Treated Effluent Disposal Facility.

2.3.8 Sub-Area #8 – Gable Mountain South

Sub-area #8 is depicted on the plate map and in Figure 2-14. The northern boundary of this sub-area borders the southern exposure of Gable Mountain, and the southern boundary occurs directly above the basalt sub-crop located north of the 200 East Area. The northwest boundary corner lies approximately 0.64 km (0.4 mi) south of West Lake, and the southwest boundary corner occurs approximately 244 m (800 ft) north of the 200 East Area's northwest fence line. The CERCLA-regulated Gable Mountain Pond is located in this sub-area.

The Gable Mountain Pond was a 29-ha (71-ac) pond located in a natural depression 2 km (1.2 mi) north of the 200 Area perimeter fence. It was the largest seepage disposal facility on the Hanford Site and operated from 1957 to 1987. The pond received large volumes of cooling water from the 202 Building and routinely received low-level effluent from various 200 East Area facilities through the PUREX cooling water line. A single UPR occurred in 1964, resulting in the discharge of approximately 7,500 Ci of mixed fission products to Gable Mountain Pond. Bentonite clay was spread over the bottom of the pond as a contamination-control measure, and copper sulfate was added to the pond twice to inhibit algae and invertebrate life in order to prevent contamination spread via the wildlife food chain.

2.3.9 Sub-Area #9 – Gable Mountain North

Sub-area #9 is depicted on the plate map and in Figure 2-15. It is triangularly shaped and is bounded to the northeast by the 200-BP-5 Groundwater OU boundary, to the south by an east-west line generally bisecting Gable Mountain, and to the west by sub-areas #1 and #2.

Sub-area #9 consists of essentially undeveloped land, with the exception of dirt roads. There are no known potential direct sources of groundwater contamination, previous operations, disposal practices, or WMAs associated with sub-area #9. The potential for liquid discharges to the unconfined aquifer is minimal.

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Figure 2-1. Map of Operable Unit Sub-Areas for 200-BP-5 Groundwater Operable Unit.

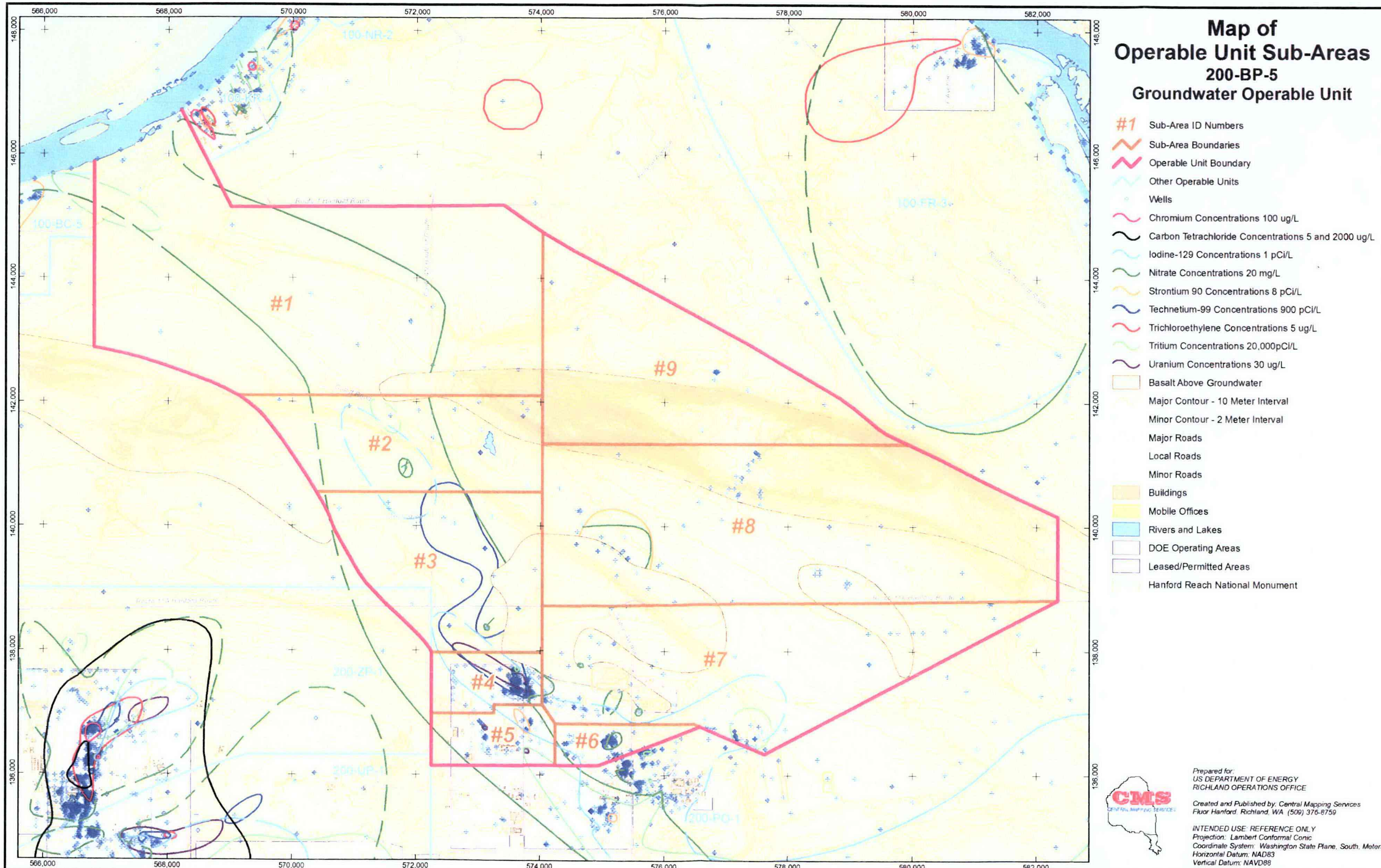
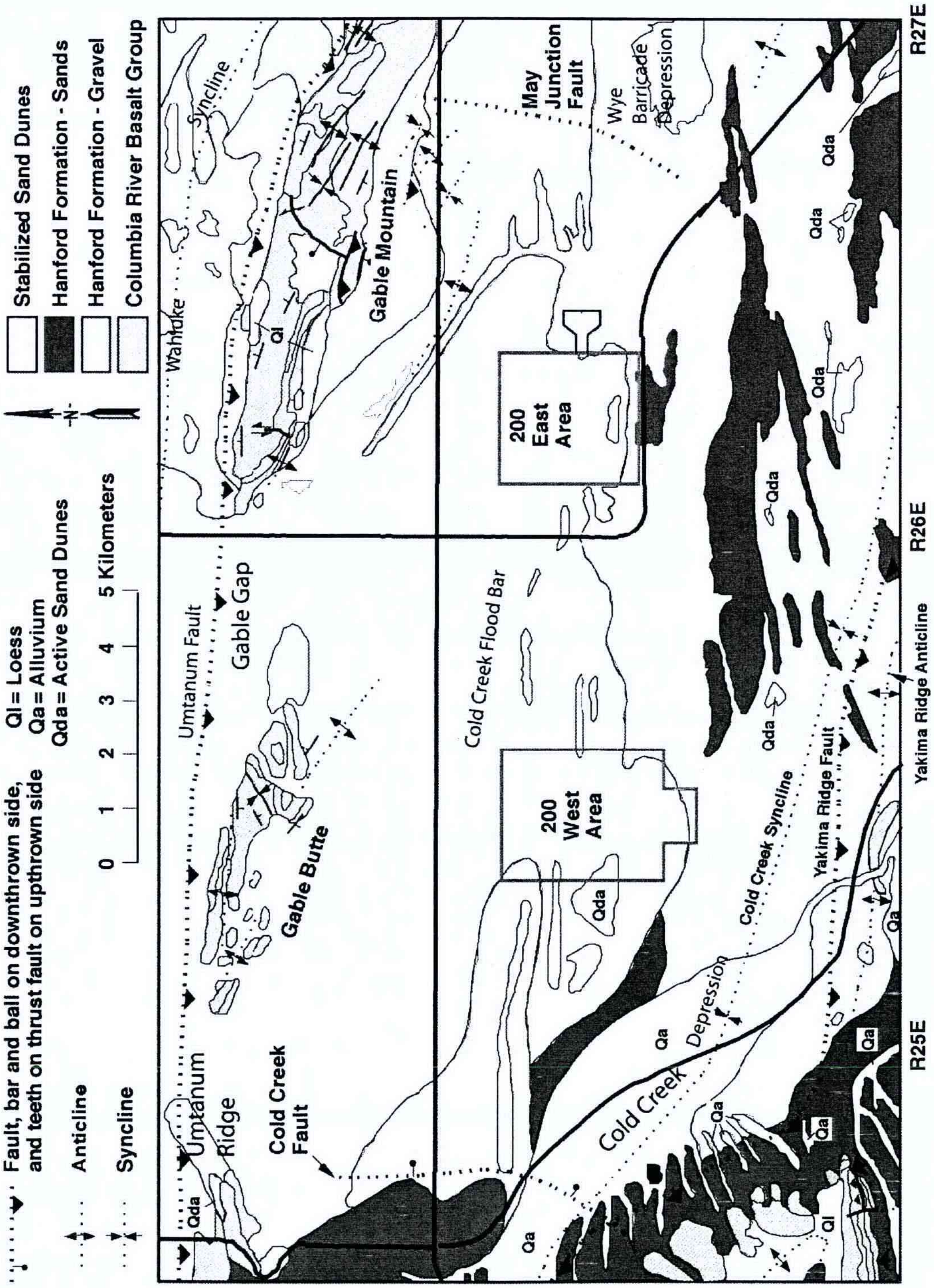


Figure 2-2. Map Showing Selected Geologic Structures and Geomorphic Features in the Vicinity of the 200-BP-5 Operable Unit.



From RPP-23748, *Geology, Hydrogeology, Geochemistry, and Mineralogy Data Package for the Single-Shell Tank Waste Management Areas at the Hanford Site.*

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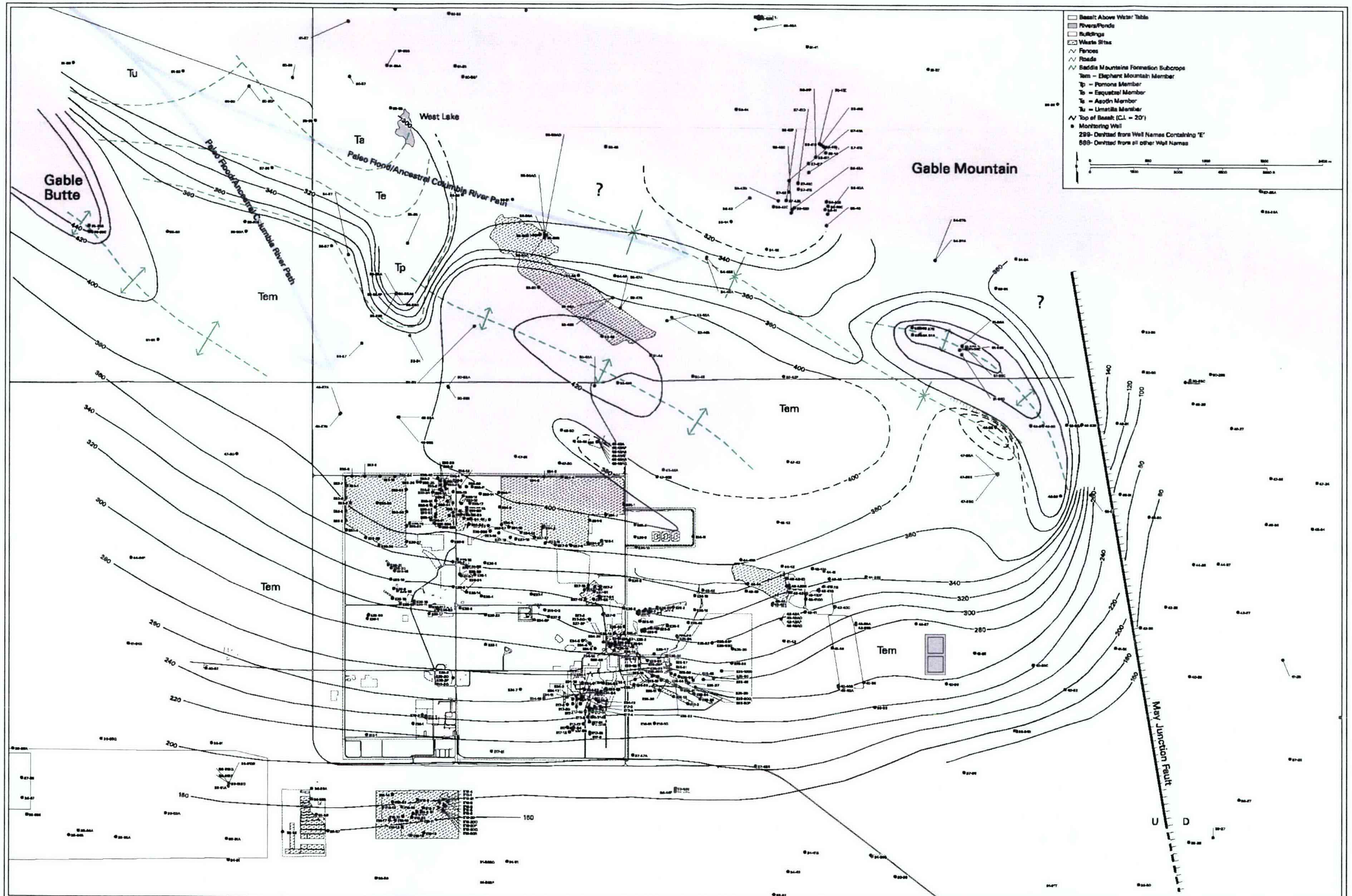
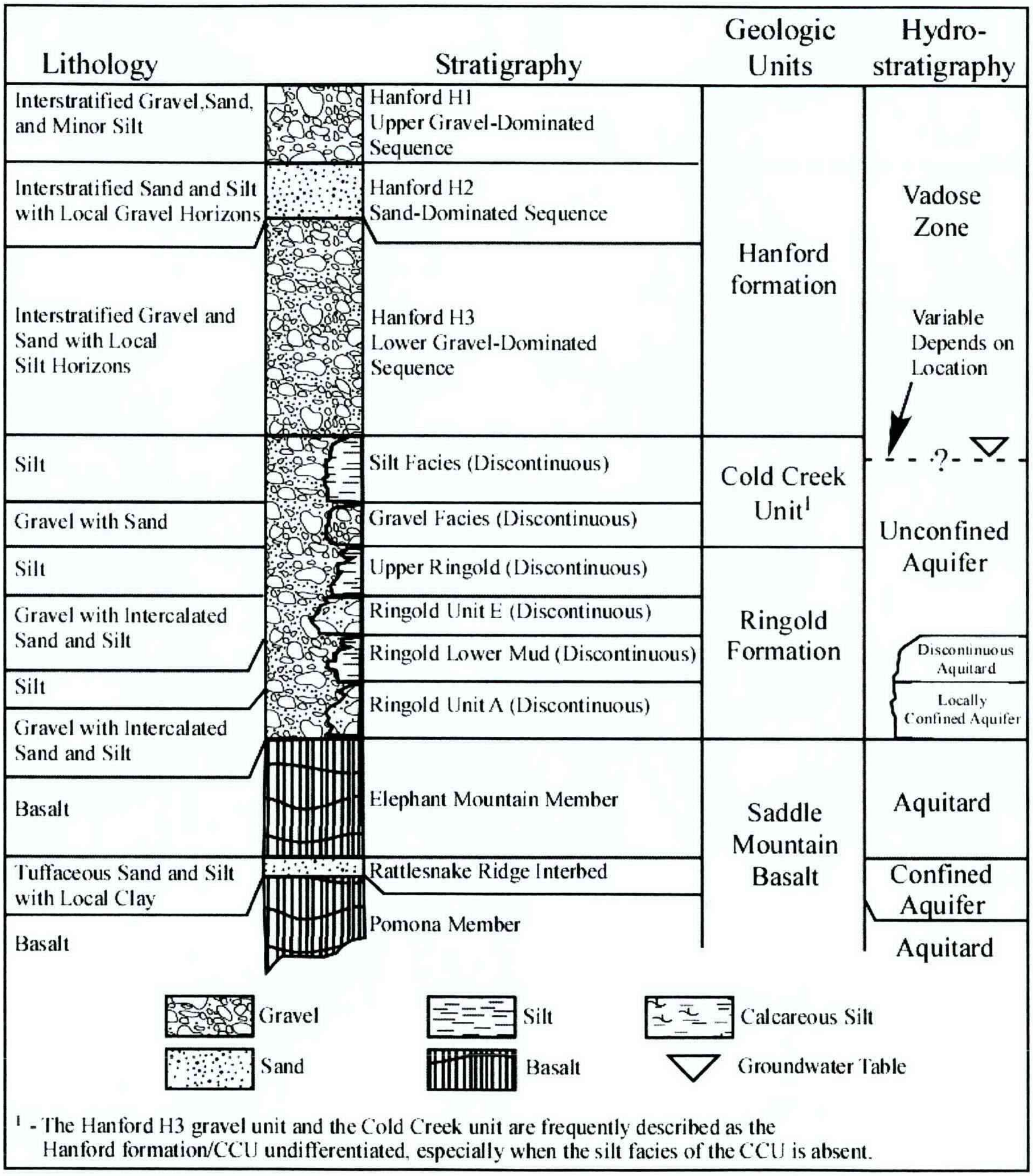
Figure 2-3. Map of Basalt Surface.



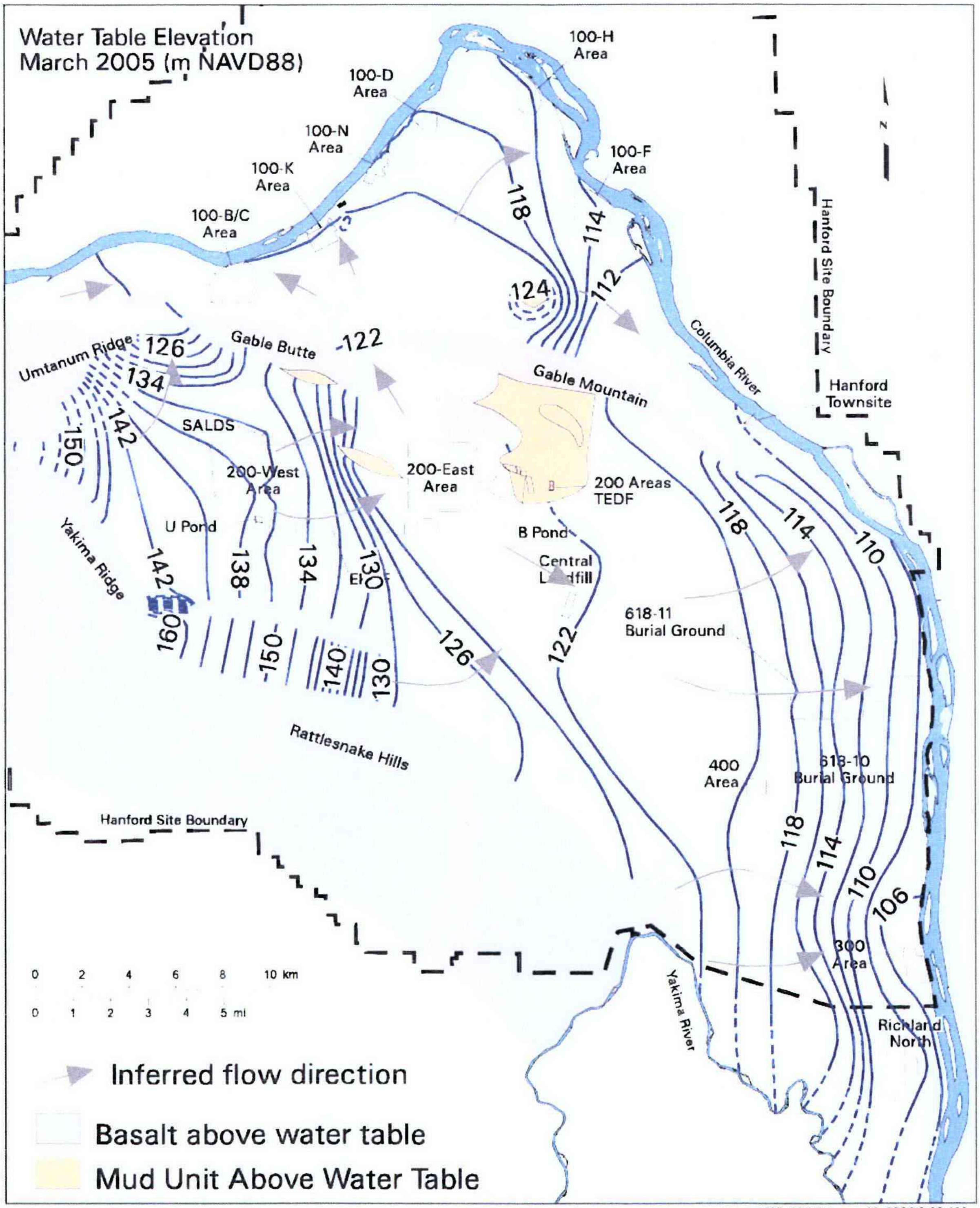
From PNNL-12261, *Revised Hydrogeology for the Suprabasalt Upper Aquifer System, 200 East Area and Vicinity, Hanford Site Washington.*

Figure 2-4. Hydrogeologic Column for 200-BP-5 Groundwater Operable Unit.



CCU = Cold Creek unit.

Figure 2-5. March 2005 Water Table Contour Map of Hanford Site Water Table.

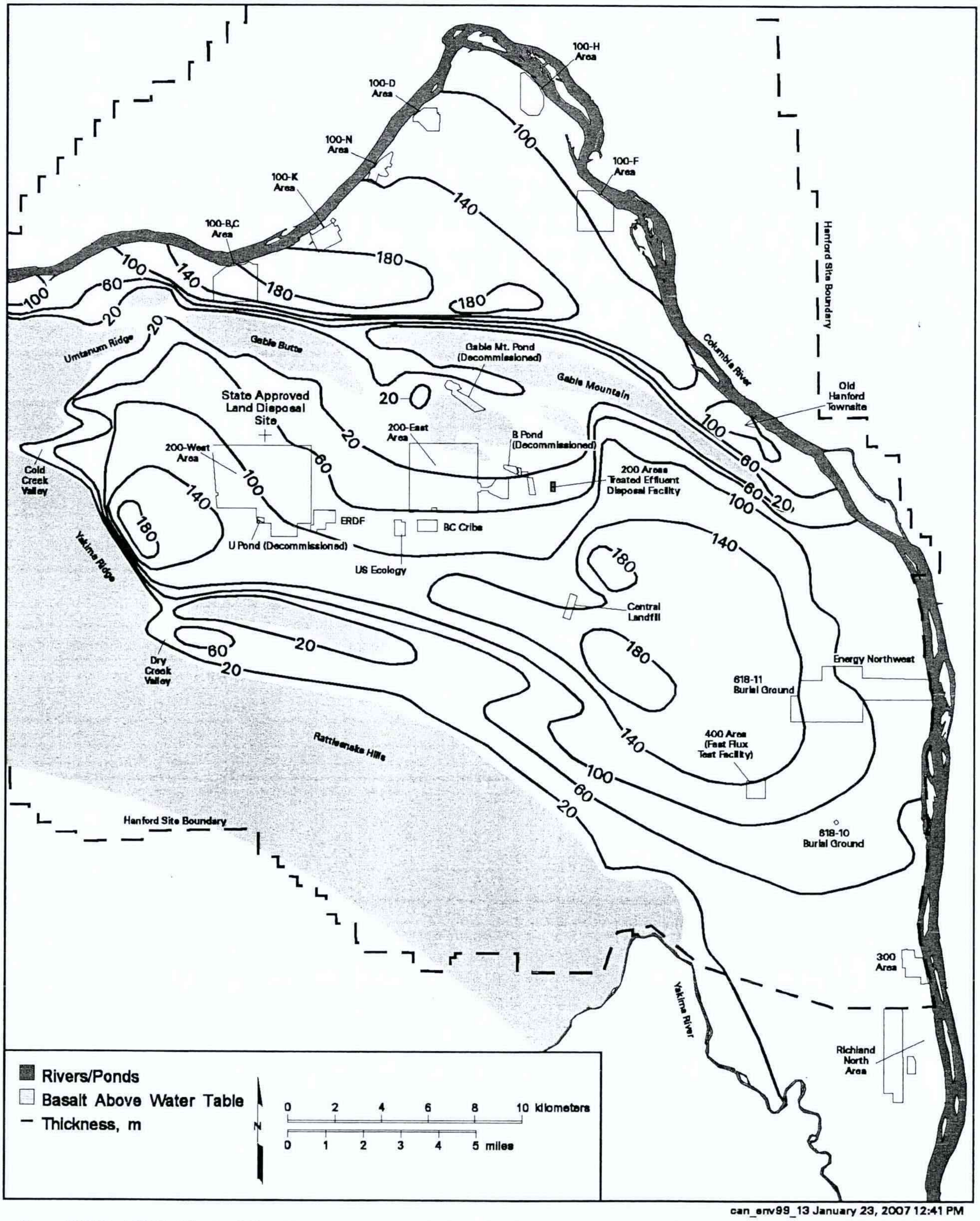


From PNNL-15670, *Hanford Site Groundwater Monitoring for Fiscal Year 2005.*

NAVD88, *North American Vertical Datum of 1988.*

ERDF = Environmental Restoration Disposal Facility.
SALDS = state-approved land-disposal site.
TEDF = Treated Effluent Disposal Facility.

Figure 2-6. Saturated Thickness of Unconfined Aquifer System in 1999.



From PNNL-13080, *Hanford Site Groundwater Monitoring: Setting, Sources and Methods.*

ERDF = Environmental Restoration Disposal Facility.

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Figure 2-7. Map Showing 200-BP-5 Operable Unit Wells in Sub-Area #1.

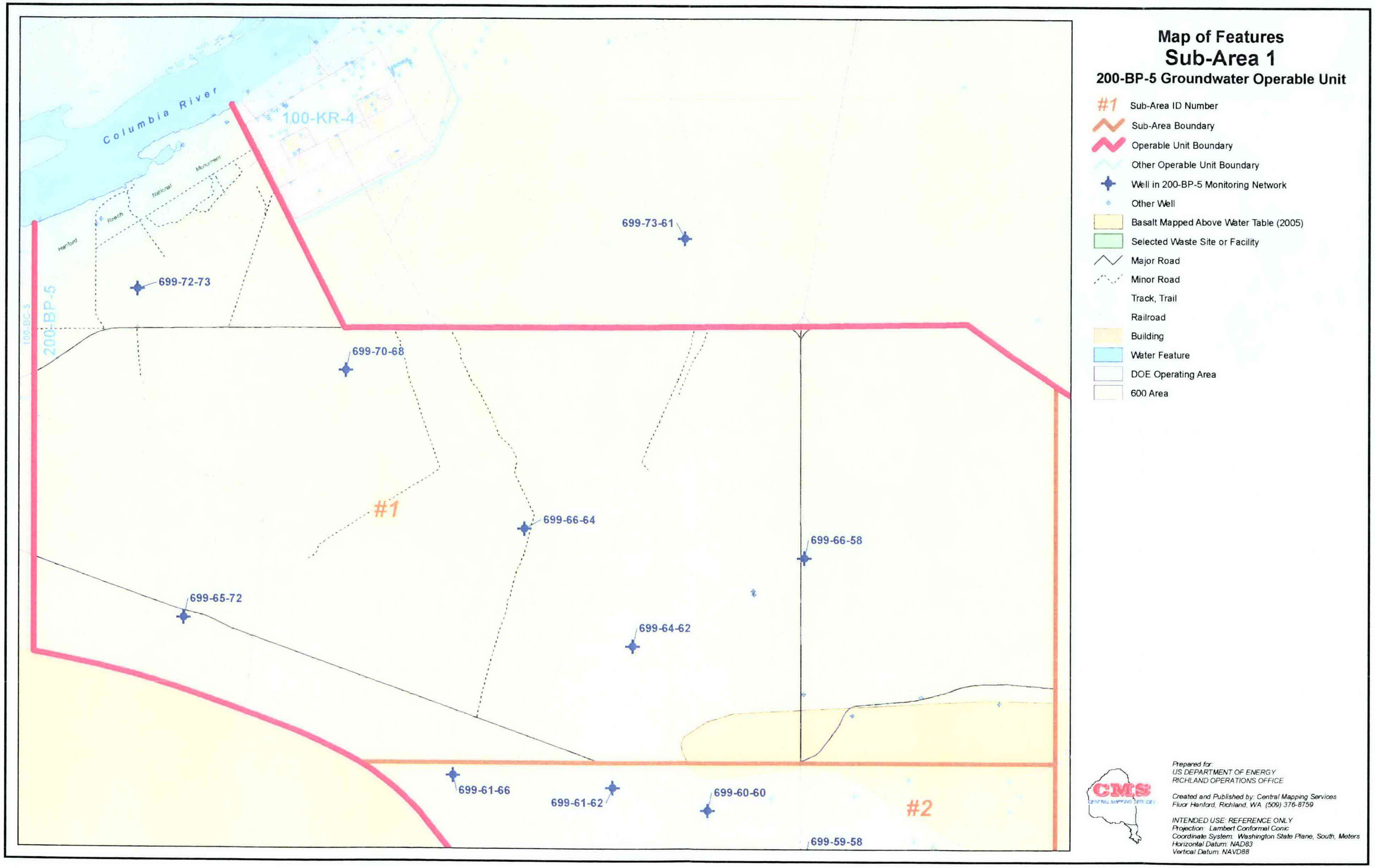


Figure 2-8. Map Showing 200-BP-5 Operable Unit Selected Monitoring Wells in Sub-Area #2.

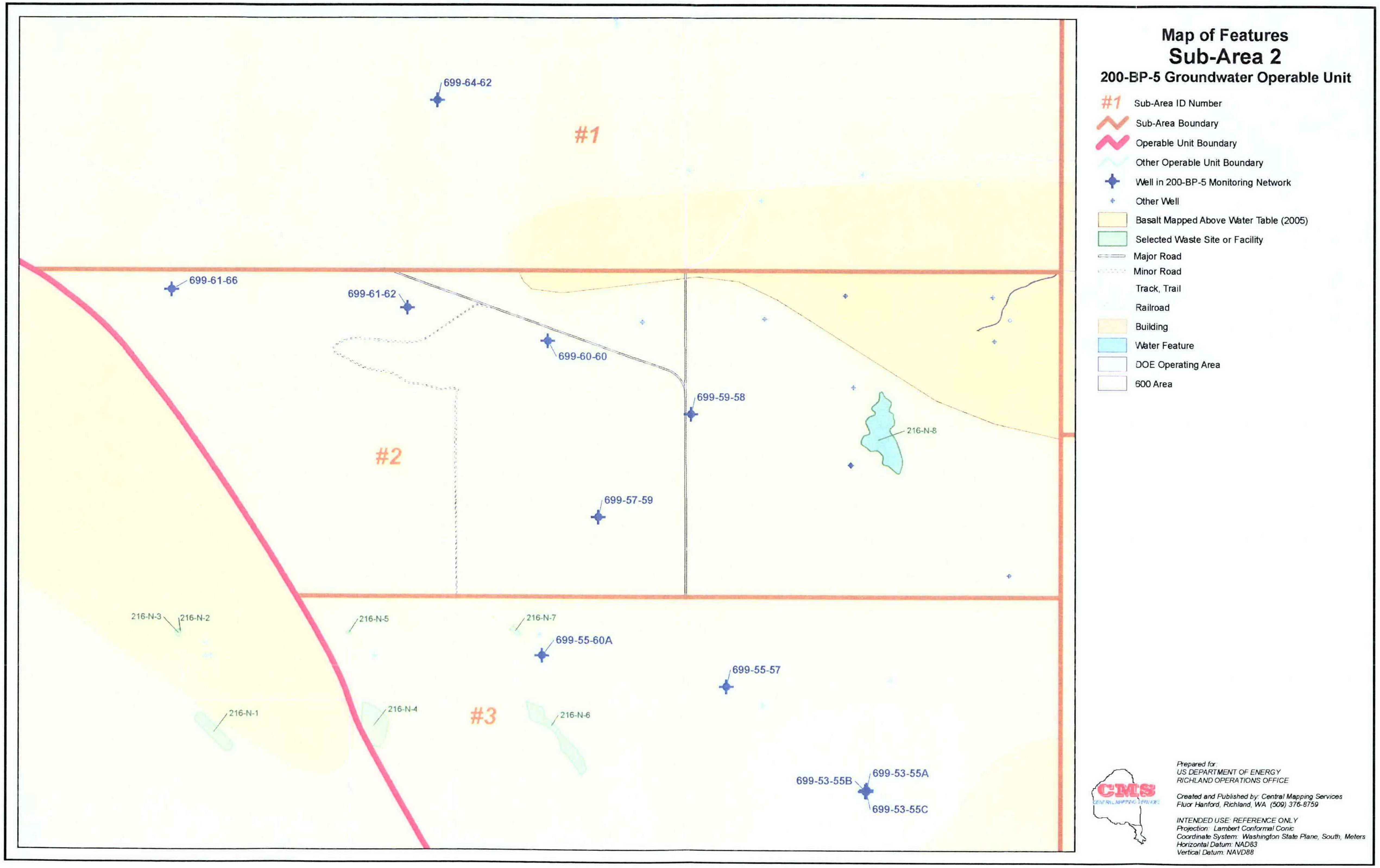


Figure 2-9. Map Showing Selected Waste Sites and Existing Monitoring Wells in Sub-Area #3.

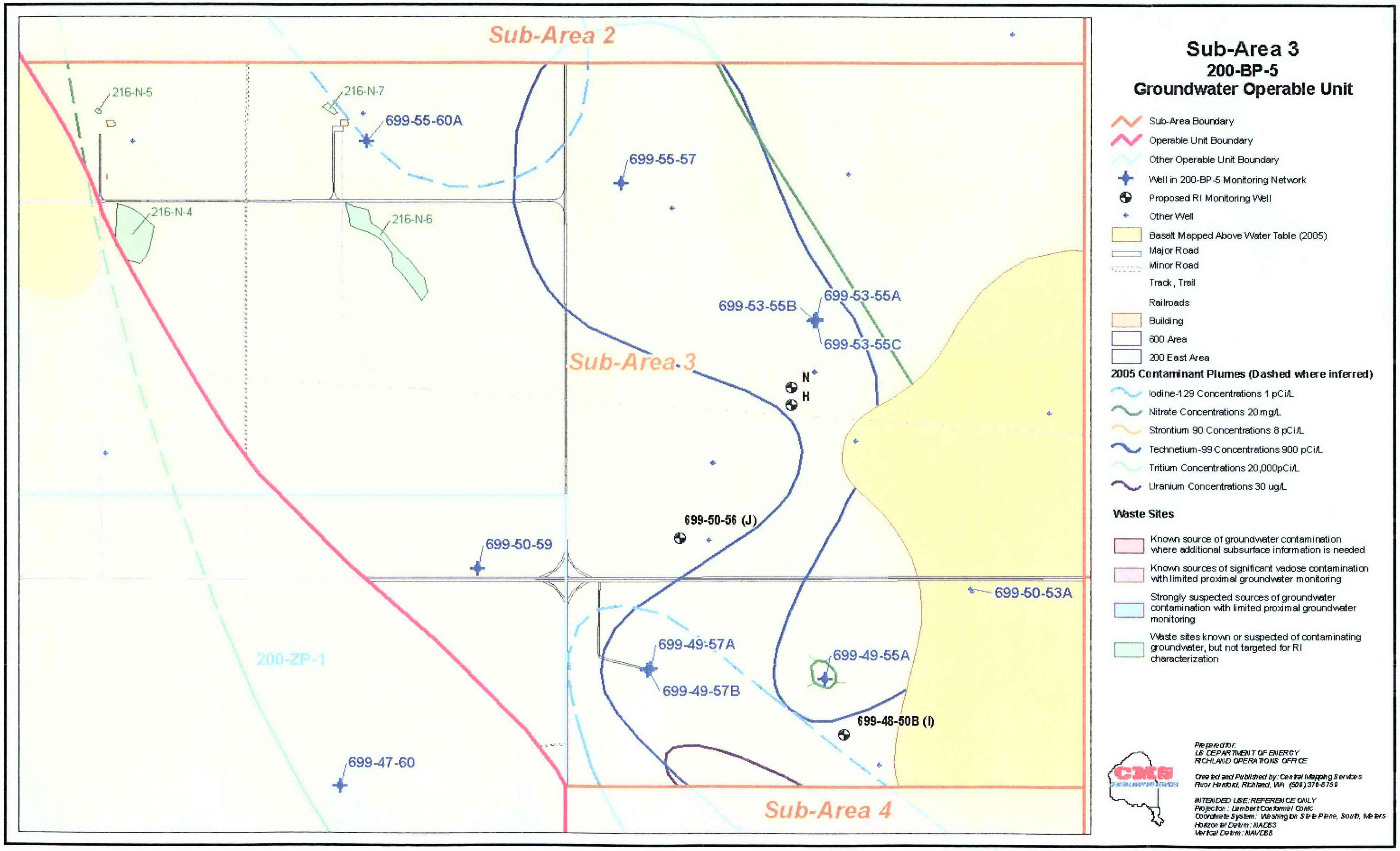
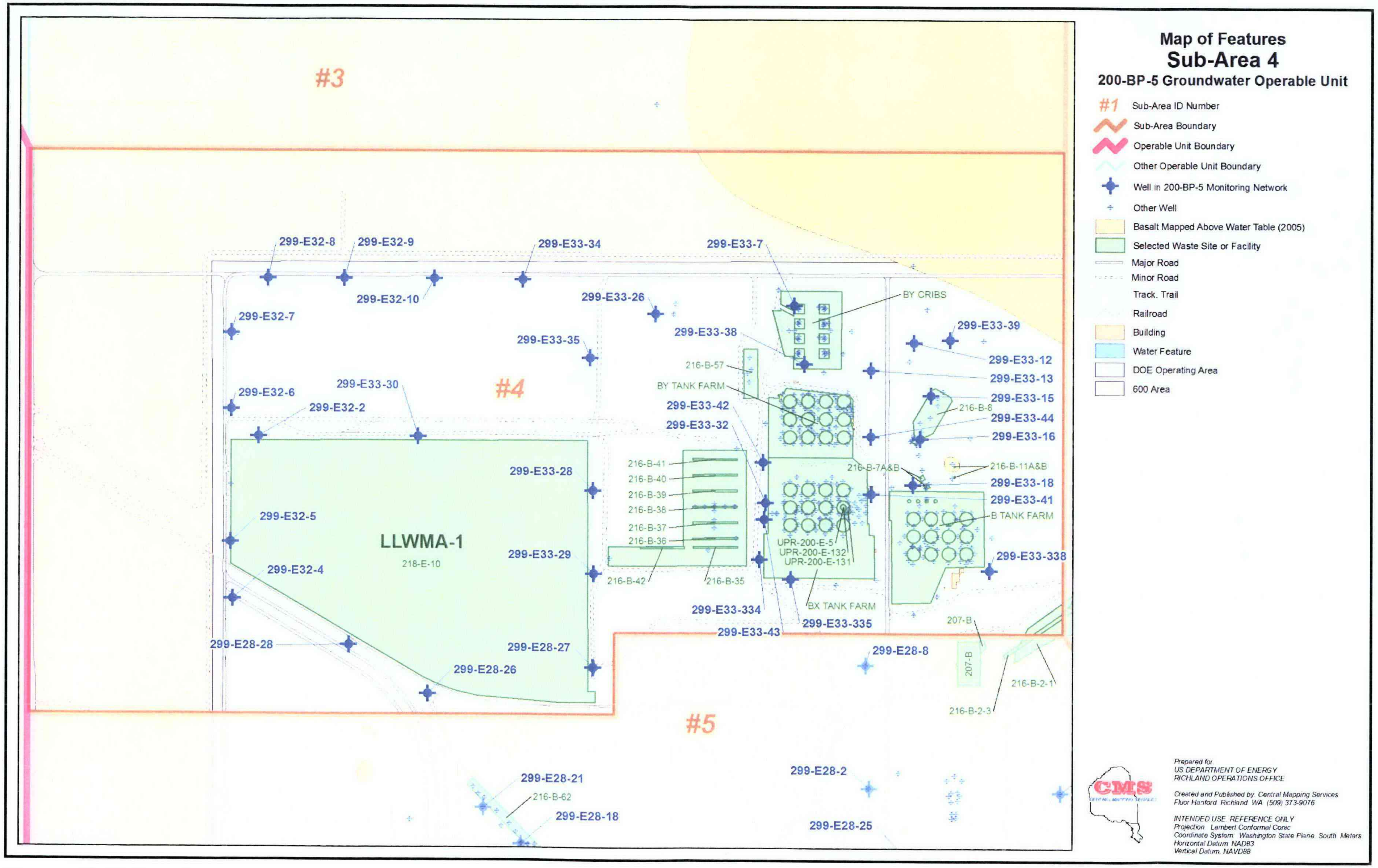
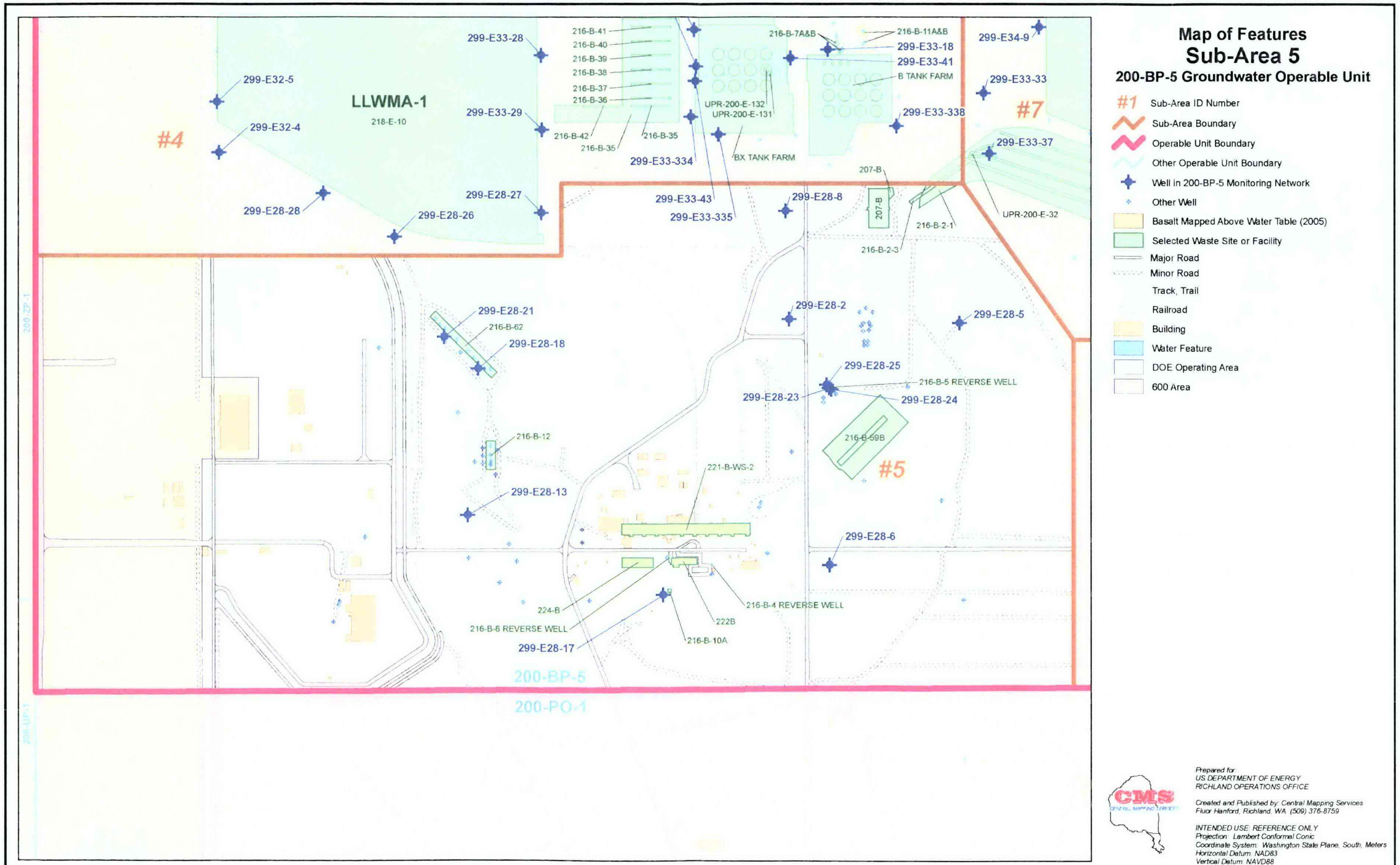


Figure 2-10. Map Showing Selected Waste Sites and 200-BP-5 Operable Unit Monitoring Wells in Sub-Area #4.



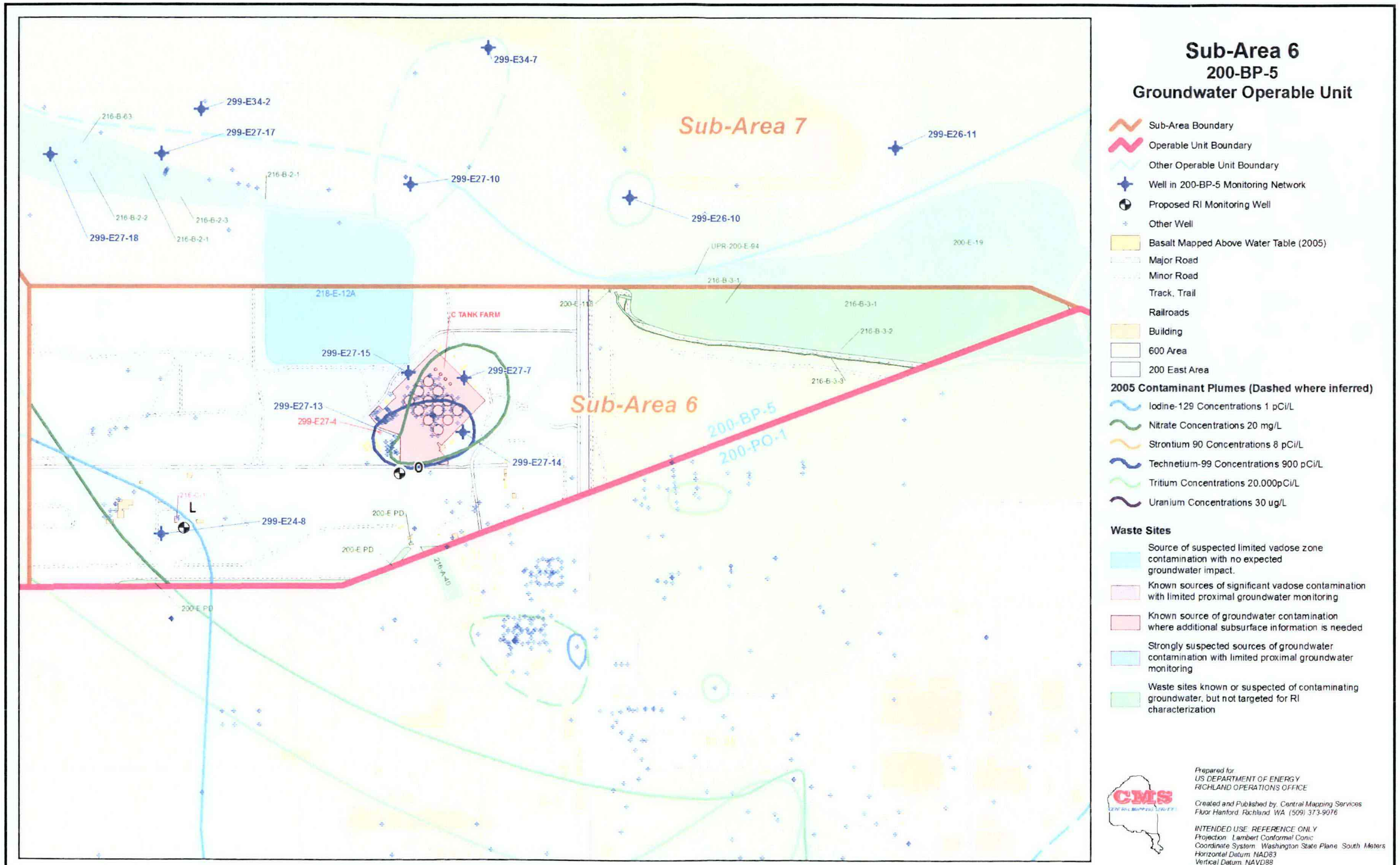
ID = identification number.
LLWMA = low-level waste management area.
UPR = unplanned release.

Figure 2-11. Map Showing Selected Waste Sites and 200-BP-5 Operable Unit Monitoring Wells in Sub-Area #5.



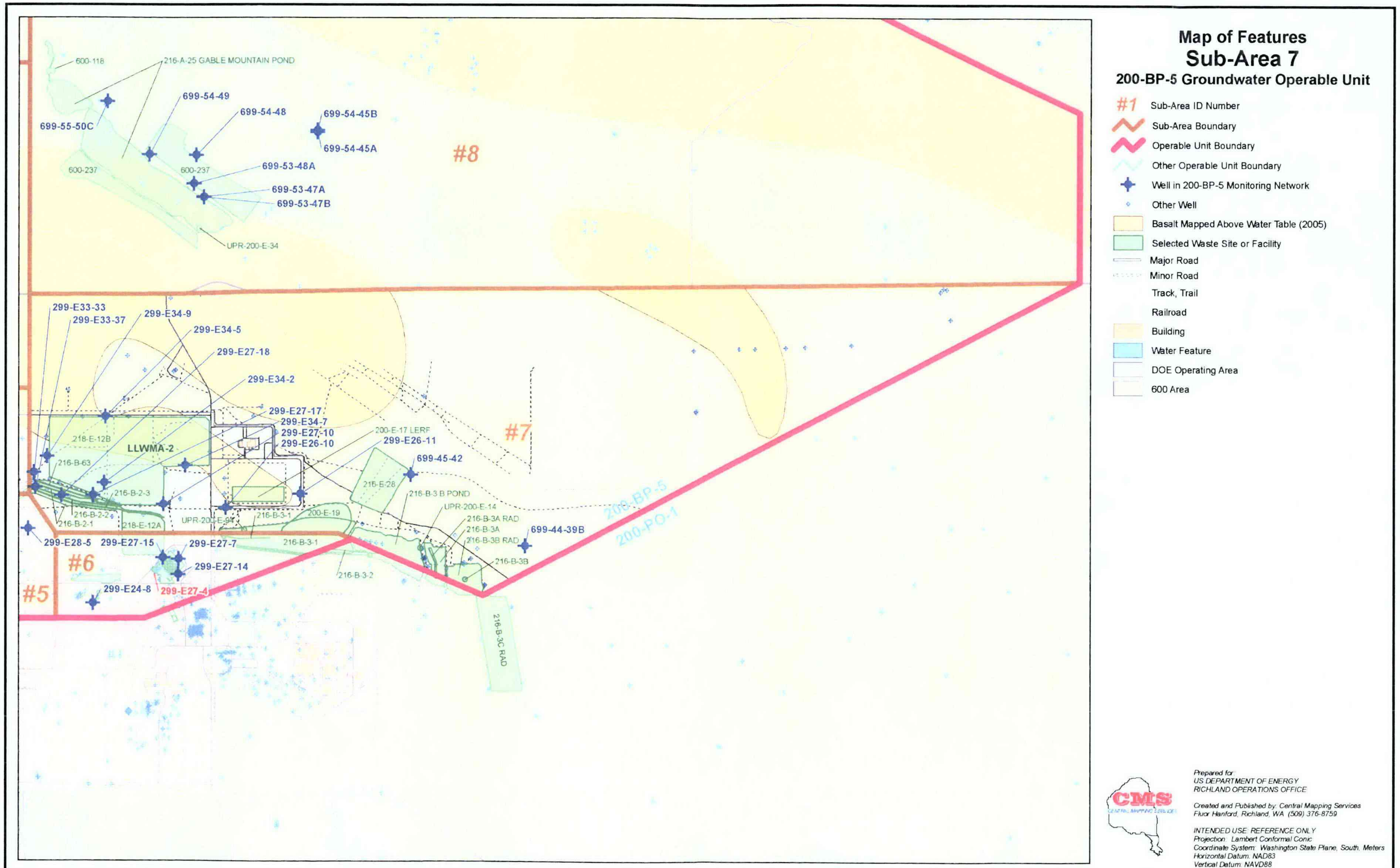
ID = identification.
LLWMA = low-level waste management area.
UPR = unplanned release.

Figure 2-12. Map Showing Selected Waste Sites and 200-BP-5 Operable Unit Monitoring Wells in Sub-Area #6.



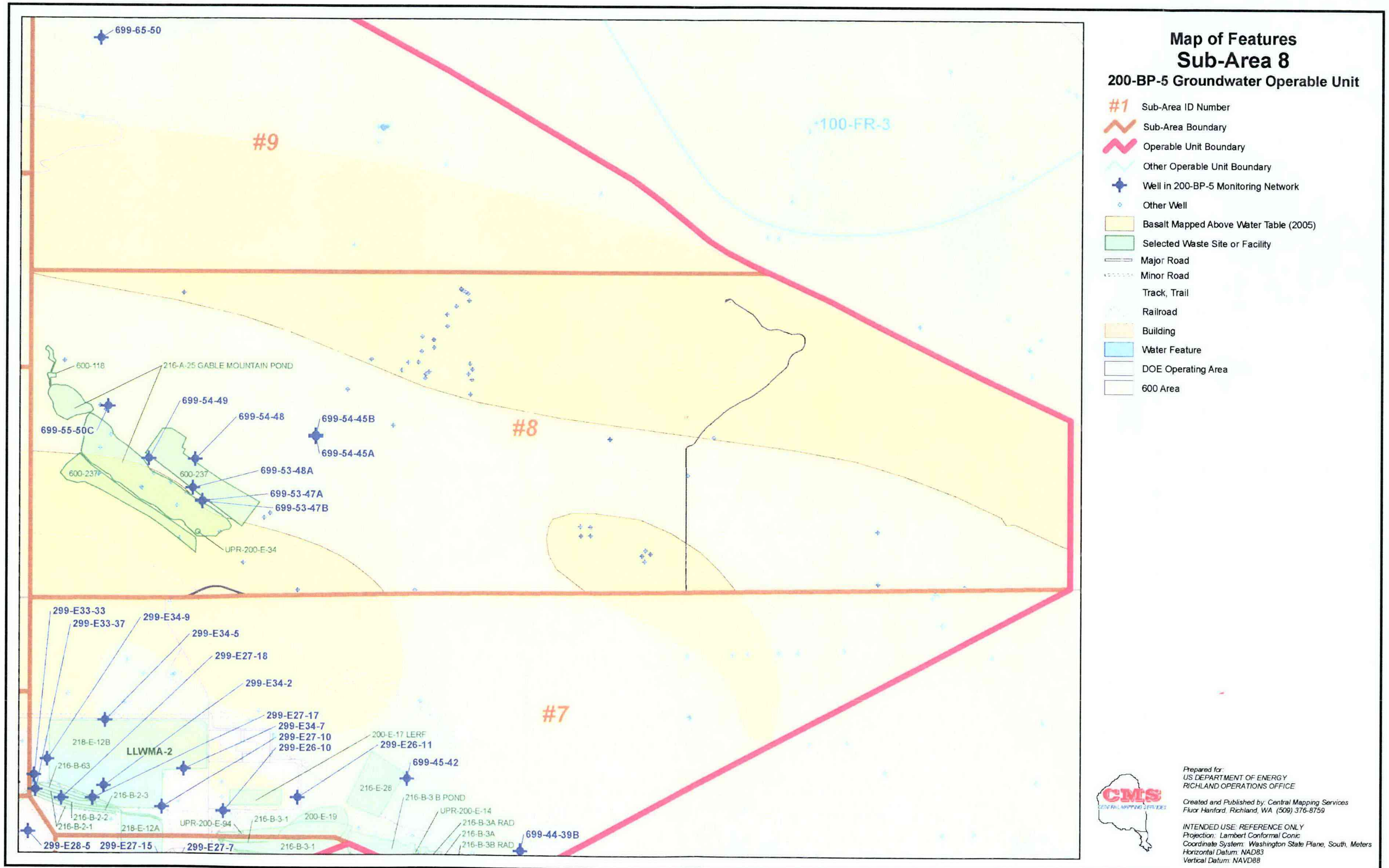
RI = remedial investigation.
UPR = unplanned release.

Figure 2-13. Map Showing Selected Waste Sites and 200-BP-5 Operable Unit Monitoring Wells in Sub-Area #7.



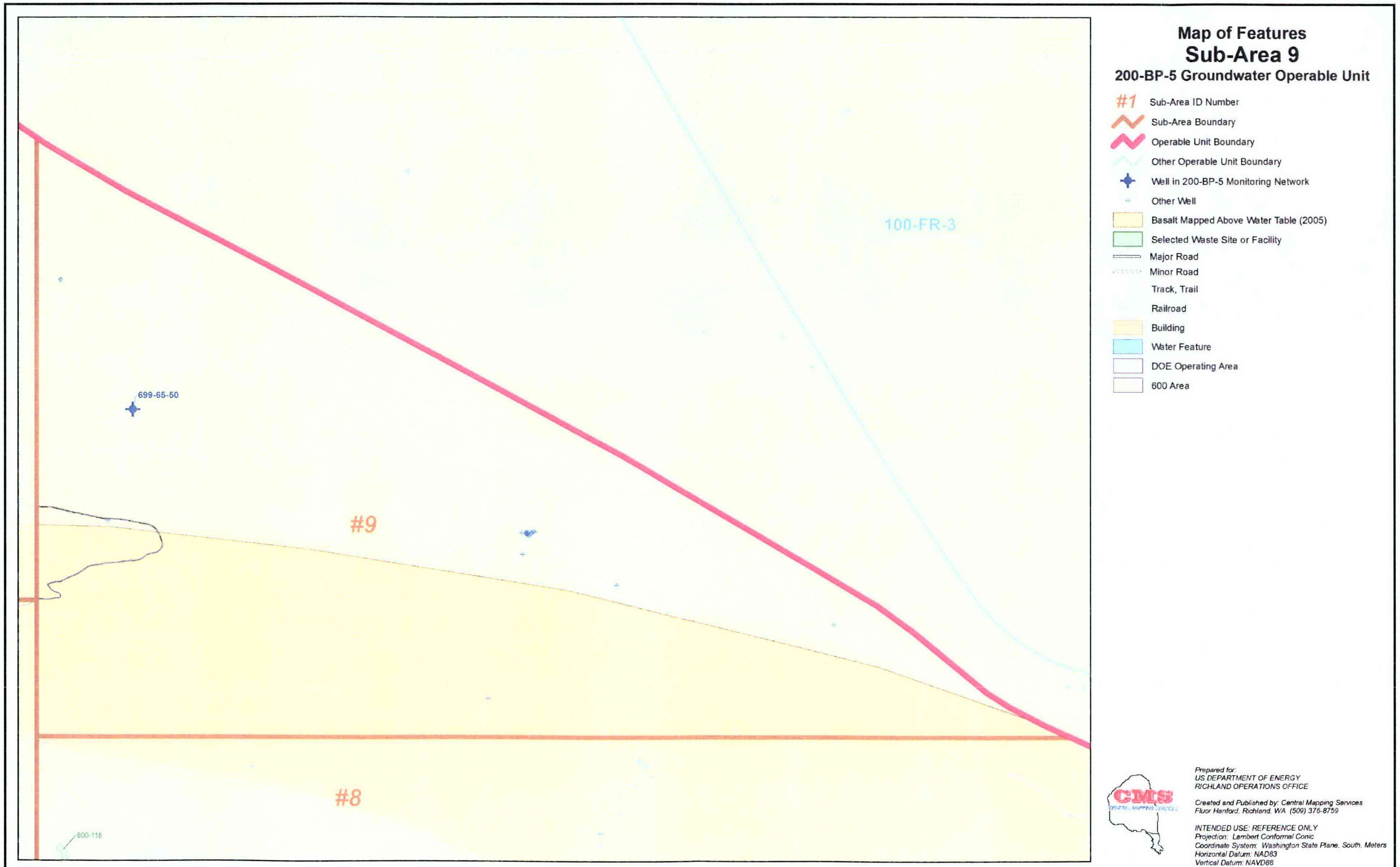
DOE = U.S. Department of Energy.
ID = identification.
LERF = Liquid Effluent Retention Facility.
LLWMA = low-level waste management area.
UPR = unplanned release.

Figure 2-14. Map Showing Selected Waste Sites and 200-BP-5 Operable Unit Monitoring Wells in Sub-Area #8.



DOE = U.S. Department of Energy.
ID = identification.
LERF = Liquid Effluent Retention Facility.
LLWMA = low-level waste management area.
UPR = unplanned release.

Figure 2-15. Map Showing Selected Waste Sites and 200-BP-5 Operable Unit Monitoring Wells in Sub-Area #9.



DOE = U.S. Department of Energy.

Table 2-1. Current Estimates of Hydraulic Conductivities for the Various Hydrogeologic Units.

Hydrogeologic Unit	Estimated Range of Saturated Hydraulic Conductivities (m/day)	References
Hanford formation	1 to 1,000,000	PNL-10886, PNL-8337
Ringold Formation Unit E	0.1 to 200	PNL-10886, PNL-8337
Ringold Formation Lower Mud Unit (aquitard)	0.0003 to 0.09	PNL-10886, PNL-8337
Ringold Formation Unit A	0.1 to 200	PNL-10886, PNL-8337
Rattlesnake Ridge interbed	0.3 to 4	WHC-SD-EN-TI-019

NOTE: This table is modified from PNNL-12261, *Revised Hydrogeology for the Suprabasalt Upper Aquifer System, 200 East Area and Vicinity, Hanford Site Washington.*

PNL-8337, *Summary and Evaluation of Available Hydraulic Property Data for the Hanford Site Unconfined Aquifer System.*

PNL-10886, *Development of a Three-Dimensional Ground-Water Model of the Hanford Site Unconfined Aquifer System: FY 1995 Status Report.*

WHC-SD-EN-TI-019, *Hydrogeologic Model for the 200-East Groundwater Aggregate Area.*

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3.0 INITIAL EVALUATION OF THE 200-BP-5 GROUNDWATER OPERABLE UNIT

The CSM for the 200-BP-5 Groundwater OU is the organizational information framework for describing contaminant sources, geology, hydrogeology, geochemistry, and contaminant plume characterization. The purpose of this chapter is to present the current understanding of the main elements of the 200-BP-5 Groundwater OU CSM, including sources, contaminant pathways, and receptors. A list of data needs associated with each of the CSMs follows each discussion. These data needs help define the work plan rationale described in Chapter 4.0 and ultimately are the basis for the work plan activities outlined in Chapter 5.0.

This chapter is organized to correspond to the major CSM elements as follows.

- The preliminary CSM is described in Section 3.1 and provides the basic framework for the RI planning efforts, the baseline risk assessment, and finally the remedial alternative evaluation and design.
- A brief summary of key overlying waste-site sources is described in Section 3.2 and provides release and contaminant information and the associated effects on the groundwater OU.
- Section 3.3 provides a summary of the major factors influencing contaminant flow and transport within the 200-BP-5 Groundwater OU, including geochemical interactions and geologic and hydrologic conditions. The hydrogeologic conceptual model originally presented in WMP-28945 also is summarized. The pathway discussion is augmented by a summary of important geologic and hydrologic information by sub-area.
- Section 3.4 summarizes the current understanding of groundwater contamination within the 200-BP-5 Groundwater OU.
- Receptor and the conceptual exposure model information is introduced in Section 3.5. The exposure scenario for the 200-BP-5 Groundwater OU is graphically represented in this section; however, certain areas require additional development.

3.1 PRELIMINARY CONCEPTUAL SITE MODEL

Several studies within the 200-BP-5 Groundwater OU have been completed in the past providing geologic, hydrogeologic, and contaminant plumes information. However, few reports have tied all the information into a focused CSM. The first of these reports was WHC-SD-EN-TI-019, *Hydrogeologic Model for the 200-East Groundwater Aggregate Area*. This report provides detailed geologic information from the Gable Mountain/Gable Butte Gap, south, to beyond the 200-BP-5 Groundwater OU boundary. One significant figure from this report presents the areal extent of the geologic formations in contact with the 1992 water table elevation (Figure 3-1). Although the water table has continued to decline, the sediment distribution remains the same at today's water table elevation; however, a larger basalt surface above the water table is present north of the 200 East Area.

The Hanford gravel sequence dominates the area in the northern portion of the 200 East Area and north to the erosional window. The erosional window is defined in Figure 3-2 where contours show thickening of the Hanford gravels. Based on the sediment distribution and limited K_h data, from pumping tests and slug tests, the site was contoured according to the various K_h values (Figure 3-3). Although more recent work has been done to update the hydraulic conductivity contours, interpretations with the updates were proven to be invalid based upon additional drilling. Therefore, the preliminary hydraulic framework has reverted to WHC-SD-EN-TI-019 until other wells planned in this work plan can be included.

This CSM (WHC-SD-EN-TI-019) also integrated contaminant plumes into the hydrogeologic frame work. The contaminant plumes movement over time is essential for developing risk assessments for the 200-BP-5 Groundwater OU due to the history of little to no discernable groundwater gradient. The flat groundwater table is evident in the December 1991 groundwater table map (Figure 3-4). The data presented in this figure show relatively no change in the groundwater elevation from the northern portion of the 200 East Area extending into the Gap. These conditions continue today even though the groundwater table has declined approximately 2 m.

Alternative methods can be used to determine groundwater movement, such as comparing plume contours over time. For some areas, within the 200-BP-5 Groundwater OU, certain contaminants appear to provide a strong case for groundwater movement. For example, a series of maps showing the averaged tritium contamination from 1997 to 2007 is compiled from past annual groundwater reports in Figures 3-5 to 3-8 (PNNL-11793, *Hanford Site Groundwater Monitoring for Fiscal Year 1997*; PNNL-13116, *Hanford Site Groundwater Monitoring for Fiscal Year 1999*; PNNL-13788, *Hanford Site Groundwater Monitoring for Fiscal Year 2001*; and PNNL-15070, *Hanford Site Groundwater Monitoring for Fiscal Year 2004*). This time series of maps illustrates present-day migration of this contaminant to the southeast. To the north of an anticlinal high where the basalt surface has been eroded forming a relatively thick aquifer, a small tritium plume was observed to migrate to the north from the late 1990s to 2002 (PNNL-13116; PNNL-13788). Also, Tc-99 in this northern area appears to be migrating in a northwest direction from well 699-53-55C to well 699-57-59 (well locations in Figure 2-8).

While groundwater flow direction in certain areas appears straightforward, based on contaminant flow, one area has had opposing views of groundwater movement based on the contaminant viewed. This area is located in the northwest corner of the 200 East Area and includes the anticlinal basalt ridge just north of the 200 East Area. The area also has been associated with several growing elevated contaminant plumes over the past decade making it a key area of interest for risk assessment. One key contaminant being used to differentiate flow direction in this area is uranium. Uranium isotopic signatures have been studied and used over the past decade to define the movement and extent of a groundwater plume apparently associated with the tank 241-BX-102 1951 release (UPR-200-E-5, Figure 2-10). Based on these studies, the uranium plume appeared to be moving quite rapidly to the north during the 1990s. Recent contouring of this plume indicates the groundwater flow has slowed significantly as seen in the uranium time series contours (Figure 3-9). As with other methods for evaluating flow direction and rate, the uranium data seem inconsistent with other data in this area. The major inconsistencies are the significant differences in the groundwater quality fingerprints at various wells within the uranium plume and the continuous concentration inconsistencies of mobile contaminants with distance for a northern flow direction within the uranium plume. An example of the latter is the trend analysis for mobile contaminants (i.e., nitrate and sodium) within the uranium plume. Generally, concentrations decrease away from the center of the plume. Within the uranium plume where uranium concentrations have been consistently the highest over the past decade, nitrate and sodium and other mobile contaminants consistently have been reported with local low concentrations. Moving to the northwest or southeast of this uranium focal point the mobile contaminant concentrations increase while the uranium decreases (Figures 3-10). This is further evident in the Stiff diagrams for the wells within the uranium plume.

Although significant historical data for the 200-BP-5 Groundwater OU exist, a revised CSM has not fully been developed due to the uncertainties expressed above. Uncertainty exists for several key parameters. These include the overlying thick and complex geology of the vadose zone, clustered waste sites with similar contaminant inventories, unknown localized recharge, flat groundwater gradient, apparent opposing groundwater flow directions, commingling of plumes, incomplete understanding of the underlying Elephant Mountain basalt elevation, and incomplete deep aquifer (e.g., greater than 15 to 20 ft) information. Though these issues exist, activities included in this work plan (e.g., electrical resistivity surveys, investigation boreholes, tracer test, geochemical analysis, and depth discrete sampling) are targeted to refine the CSM for development of a defensible baseline risk assessment. As these data are collected and evaluated, a detailed CSM report will be completed to refine the framework for the baseline risk assessment.

The following paragraphs provide observations revealed through the DQO process. The observations help to express the complications associated with integration of the elements of source, release mechanisms, pathways, and receptors as a basis to evaluate current and potential future site risks.

3.2 KNOWN AND POTENTIAL SOURCES

A thorough review and evaluation of the potential overlying sources of groundwater contamination was conducted during the 200-BP-5 Groundwater OU DQO process, and the results of this review are summarized in WMP-28945. The preliminary CSM developed for this work plan focuses not only on the groundwater but on the overlying waste sources identified as known or potential contributors to groundwater within the 200-BP-5 Groundwater OU. The list of potential or known contributors was subdivided by the major source category, including SSTs and ancillary equipment (e.g., pipelines, valves), cribs, ditches, trenches, ponds, reverse wells, vadose zone contamination, and miscellaneous UPRs. The following subsections summarize each of these waste sources in their respective source category.

3.2.1 Tanks

Several SSTs overlie the 200-BP-5 Groundwater OU and were constructed to store high-level radioactive waste generated during the chemical processing of irradiated fuel materials at the chemical separation plants. Releases of waste volumes to the environment during transfer of materials or as a result of breach of containment within the tanks has been documented, both during operations and following the removal of the tanks from service (RPP-10098).

The identification of all tanks that have leaked and the definitive quantities of waste released to the vadose zone remain uncertain. Historically, tank leakage was evaluated using direct waste-volume measurements (i.e., depth to top of waste) within the tanks and using borehole gross-gamma and/or spectral-gamma surveys in the network of tank farm dry wells. Groundwater monitoring also has been used to evaluate potential tank leakage; however, deep groundwater conditions and sparse well coverage limit the effectiveness of this method in precisely locating the contaminant source. Overall, each of these methods has limitations for identifying the nature and extent of contamination and the precise source of leakage from a tank.

Currently, high-resolution resistivity (HRR) surveys are being deployed at SST farm WMAs. This geophysical method is undergoing evaluation to determine its utility for identifying higher moisture and/or salt zones possibly associated with contamination transport beneath the tank farms. The extent of contamination released to the vadose zone and groundwater beneath the SST WMAs is under investigation through the RCRA remedial field investigation/corrective measures study (RFI/CMS) process. Tanks and ancillary equipment overlying the 200-BP-5 Groundwater OU currently known or suspected to contribute to groundwater contamination are summarized below:

- <u>WMA-B/BX/BY SSTs and ancillary equipment</u>: Leaks and spills associated with SSTs and ancillary equipment located within the WMA-B/BX/BY Tank Farm (Figure 2-10, sub-area #4) appear to have contributed tritium, nitrate, Tc-99, and uranium that migrated from the vadose zone into groundwater (PNNL-11826, *Results of Phase I Groundwater Quality Assessment for Single-Shell Tank Waste Management Areas B-BX-BY at the Hanford Site*). The largest release was UPR-200-E-5, which occurred in 1951 when tank 241-BX-102 was receiving metal waste from the B Plant. The incident occurred when a cascade outlet to tank 241-BX-103 became plugged, releasing approximately 348,257.9 L (92,000 gal) of liquid to the soil near the tank. Tank 241-BX-102 also released waste in an apparent breach of containment that was detected in 1971, but was later documented to have occurred in 1951 (RPP-10098). Twenty individual tanks have been identified as assumed leakers within the WMA-B/BX/BY Tank Farm, including tank 241-BX-102.

- <u>WMA-C SSTs and ancillary equipment</u>: Leaks and spills associated with the SSTs and ancillary equipment located within the C Tank Farm (Figure 2-12, sub-area #6) appear to have contributed Tc-99, nitrate, and low concentrations of cyanide to the groundwater. Tank 241-C-101 reportedly released 64,352 to 90,849.9 L (17,000 to 24,000 gal) of waste containing 2,000 Ci between 1946 and 1970. Contaminant concentrations in the groundwater at this facility began rising between 1995 and 1998, depending on the monitoring location, and consist primarily of elevated nitrate and Tc-99. Four new wells have been added to provide further information regarding the contaminant source (PNNL-14548, *Hanford Site Groundwater Monitoring for Fiscal Year 2003*).

3.2.2 Cribs, Trenches, Ditches, and Ponds

Liquid waste was discharged directly to the soil column via cribs, ponds, trenches, and ditches. Because the large volumes of discharged effluent were not contained, the liquid waste exceeded the estimated available pore space. Thus, there were large vertical heads driving fluids during active disposal. In addition, the disposal practices allowed for the potential of significant horizontal spreading of fluids and dissolved constituents. Some of the contaminants associated with the releases have low distribution coefficients (K_d) increasing contaminant mobility. Many of the wells monitoring these sites are currently reported with elevated contamination. These waste sites represent the highest risk of current and future groundwater contamination within the 200-BP-5 Groundwater OU and are summarized below:

- <u>216-BY Crib complex</u>: The BY Crib complex is located in sub-area #4, north of the WMA-B/BX/BY Tank Farm (Figure 2-10). These cribs are identified as the primary sources of Tc-99, cyanide, Co-60, and nitrate groundwater contamination in that area. The BY Cribs also are a potential source of uranium contamination. Currently, groundwater in the vicinity of the BY Cribs contains some of the highest Tc-99, cyanide, nitrate, and gross-beta concentrations within the 200-BP-5 Groundwater OU.

- <u>216-B-8 Crib</u>: This crib is located in sub-area #4, north of the B Tank Farm (Figure 2-10). Groundwater monitoring in the vicinity of the 216-B-8 Crib indicates that it is a potential source of nitrate contamination. Low concentrations of nitrite and uranium appear to be associated with this crib. Current nitrate concentrations appear to be migrating preferentially east/southeast. Historically, this site was identified as a source of uranium and gross-beta contamination and other co-contaminants. In addition, uranium isotope ratio data (e.g., U-236) have indicated that uranium in the groundwater beneath the 216-B-8 Crib is not associated with the WMA-B/BX/BY Tank Farm (PNNL-13763, *Investigation of Isotopic Signatures for Sources of Groundwater Contamination at the Hanford Site*).

- <u>216-B-62 Crib</u>: This crib is located northwest of the B Plant, in sub-area #5 (Figure 2-11). A uranium plume has been monitored from 1985 to present and is located beneath and north of the 216-B-62 Crib waste site. Past annual groundwater reports have associated uranium groundwater contamination with this waste site. However, this site's uranium inventory calculation indicates that the 216-B-62 Crib received only approximately 1 kg (which is the median value from the recent Soil Inventory Model) (RPP-26744, *Hanford Soil Inventory Model, Rev. 1*). No reported uranium concentrations were found in the *Hanford Environmental Information System* database (HEIS) for the monitoring wells near this waste site before 1985 when the contaminant plume already was established.

- <u>216-B-7A and -7B Cribs</u>: These cribs are located north of the B Farm and south of the 216-B-8 Crib, in sub-area #4 (Figure 2-10). The cribs operated from 1946 to 1967 and received a total volume of 43.5 million L (11.5 million gal) of B Plant liquid effluent. Radionuclides contained within the waste stream include Cs-137, Ru-106, Sr-90, plutonium, uranium, and other fission products. A previous investigation and associated modeling results indicated that the following constituents would require periodic groundwater monitoring if a passive remedial alternative were selected: cyanide, fluoride, nitrate, Tc-99, U-233/234/238, and Sr-90. Of these constituents, only nitrate and tritium were detected at depths in the investigation borehole with potential to impact the groundwater in the near future (less than 20 years). Recent geophysical survey results at proximal well 299-E33-18 have detected significant uranium concentrations possibly associated with the 216-B-7A Crib in deep vadose sediments above the aquifer. However, a previous investigation involving boreholes drilled within the footprint of the 216-B-7A Crib resulted in sample results that were below background concentrations for uranium at soil depths greater than 11.4 m (37.5 ft) bgs. Therefore, additional information is required to determine potential emerging contaminants and concentrations for groundwater protection.

- Gable Mountain Pond: Localized groundwater plumes of Sr-90 and nitrate occur in the vicinity of Gable Mountain Pond, located in sub-area #8 (Figure 2-14). Strontium in this area, as at the 216-B-5 Reverse Well, is considered to be decayed within the next 300 years before migrating a significant distance.

3.2.3 Reverse Wells

WMP-28945 identified two reverse wells (216-B-5 and 216-B-6), located in the B Plant aggregate area, as known or suspected sources of groundwater contamination. The reverse wells were used to inject wastewater into the ground at a greater depth than possible with cribs or french drains. Also like the cribs, trenches, ditches, and ponds, releases to the reverse wells had the potential of large vertical heads driving fluids during active disposal. In addition, the various changes in soil horizons along with the disposal practices allowed for the potential of significant horizontal spreading of fluids and dissolved constituents.

- 216-B-5 Reverse Well: The 216-B-5 Reverse Well discharged wastewater directly to the groundwater. Monitoring wells associated with the 216-B-5 Reverse Well in sub-area #5 have had detectable concentrations of Sr-90, Cs-137, Pu-239/240, and uranium in groundwater samples. The risk-based decisional analysis associated with the 200-BP-5 Treatability Test Report (DOE/RL-95-59) concluded that the 216-B-5 Reverse Well plumes will produce an acceptable risk to off-site groundwater users. Specifically, Cs-137 and Sr-90 would not reach the 200 East Area boundary before decaying to negligible levels. Plutonium-239/240, after a travel time of 7,500 years would reach the southern boundary of the industrial zone and have a maximum Pu-239/240 concentration of 0.2 pCi/L. The contoured incremental lifetime cancer risk was 6E-7.

- 216-B-6 Reverse Well: The 216-B-6 Reverse Well is located south of the 222-B Building, in sub-area #5 (Figure 2-11). The site received liquid effluent from decontamination sinks and sample slurper waste from the 222-B Building from 1945 to 1949. The waste inventory indicates that this waste site received 22.7 million L (6 million gal) of effluent with 100 kg of $Na_2Cr_2O_7$. However, recent median Soil Inventory Model estimates indicate that nearly 2,500 kg of chromium were disposed to this waste site. The construction of the reverse well is uncertain, with three conflicting screen intervals (i.e., 23 m [75 ft] bgs, 49 m [161 ft] bgs, and 92 m [302 ft] bgs) presented in the databases. The WIDS database indicated that this waste site was similar to the discharges associated with the 222-T Laboratory, with 2.6 Ci of fission product and 600 mg of plutonium per month. A lack of proximal groundwater-monitoring wells, high inventory levels for chromium and nitrate, and uncertainty of the depth of the 216-B-6 Reverse Well are the basis for further information requirements for this site.

3.2.4 Vadose Zone Contamination Potentially Impacting Groundwater

Vadose zone contamination represents a potential source of future groundwater contamination. The vertical migration of vadose zone contaminants to groundwater requires a driving force (i.e., water or waste liquids) sufficient to overcome the geochemical and physical factors inhibiting transport (see Section 3.3). The following list includes known or suspected locations of vadose zone contamination overlying the 200-BP-5 Groundwater OU boundary. As mentioned in Section 3.2.2, both of these sites received significant volumes of discharged effluent that exceeded the estimated available pore space.

- 216-B-12 Crib: The 216-B-12 Crib is located west of B Plant in sub-area #5 (Figure 2-11). Sediments below the 216-B-12 Crib are known to contain elevated concentrations of uranium, tritium, and nitrate. This was confirmed during the drilling of borehole C3246 in support of the RI/FS for the 200-PW-2 OU (PNNL-15070, *Hanford Site Groundwater Monitoring for Fiscal Year 2004*; DOE/RL-2004-25, *Remedial Investigation Report for the 200-PW-2 Uranium-Rich Process Waste Group, and 200-PW-4 General Process Condensate Group Operable Units*). The borehole was located within the 216-B-12 Crib. Using conservative modeling with the RESidual RADioactivity dose model, only tritium is modeled to impact groundwater from this site over the next 1,000 years (DOE/RL-2004-25). The analysis of alternatives in the associated FS indicated that nitrite, nitrate, and total uranium within the soils beneath the 216-B-12 Crib exceed groundwater protection levels for all alternatives except removal. Uranium inventory calculations for the 216-B-12 Crib indicate that this site received 15,112 kg (which is a median value from the recent Soil Inventory Model) (RPP-26744).

- 216-C-1 Crib: The 216-C-1 Crib is located near the Hot Semiworks Plant in sub-area #6 (Figure 2-12). Significant vadose zone contamination is likely beneath the 216-C-1 Crib. The crib received 88.6 million L (23.4 million gal) of high-salt waste, cold-run waste, and process condensate of experimental REDOX and PUREX Plant effluent. Waste inventories for nitrate and chromium were estimated at 2,761,900 kg and 57,700 kg, respectively. The ratio of effluent to pore space was calculated at 29.8 during the operating period. Historic groundwater analytical results from well 299-E24-8 (downgradient of the 216-C-1 Crib during active B Pond effluent discharges) only covered part of the COPCs. The nitrate data reported in the 1960s from wells 299-E27-5 (upgradient) and 299-E24-8 (downgradient) indicate possible contributions from the 216-C-1 Crib.

3.2.4.1 Data Needs Related to Potential Groundwater Contamination Sources

Identification of contaminant sources is important to understanding the nature and extent of existing groundwater contamination and allows the evaluation of potential future groundwater contamination from migrating contaminants in the vadose zone. The term "deep vadose" is used to describe sediments above the water table but greater than approximately 30.5 m (100 ft) bgs. The following data needs regarding groundwater contamination sources were identified.

- Vadose zone and groundwater data are needed in the vicinity of tank 241-BX-102 and the BY Crib complex to help identify the nature and extent of deep vadose zone contamination and groundwater contamination in the area.
- Additional data are necessary in the vicinity of the WMA-C Tank Farm to explain increasing concentrations of nitrate and Tc-99 in area monitoring wells.
- Additional data are necessary to further substantiate the source of uranium in groundwater beneath the WMA-B/BX/BY Tank Farm.
- Vadose zone data are needed to further investigate the source (i.e., possibly the 216-B-7A Crib) of significant uranium concentrations measured during recent borehole geophysical logging of well 299-E33-18.
- The RESidual RADioactivity dose model for the 216-B-12 Crib indicated that nitrate/nitrite, nitrate, and total uranium within the sediments beneath the crib exceed groundwater protection standards for all alternatives except removal. Additional investigation of the vadose zone contamination is necessary to predict potential future impacts to groundwater.
- Additional contaminant of potential concern (COPC) analyses of deep vadose zone sediment in the vicinity of the 216-C-1 Crib may be necessary to understand potential groundwater impacts from probable vadose zone contamination.

3.3 PATHWAY ASSESSMENT

Contaminant transport through the vadose zone and aquifer is influenced by a number of geochemical and physical factors. Understanding the primary factors influencing contaminant movement in the overlying sediments and within the 200-BP-5 Groundwater OU is critical to understanding the risks posed to potential receptors from existing and potentially emerging groundwater contamination. The following subsections summarize the various major influences on contaminant movement and identify the respective data needs associated with each. These data needs will be the primary focus for the RI activities described in Chapter 5.0.

3.3.1 Vadose Zone Stratigraphy

The detailed geologic setting of the overlying sediments and within the 200-BP-5 Groundwater OU is described in Section 2.2. This section focuses on the stratigraphy of the vadose zone overlying the 200-BP-5 Groundwater OU. Vadose zone stratigraphy controls downward contaminant migration to the groundwater. In particular, the hydraulic characteristics of continuous and discontinuous strata influence transport of contaminants and affect infiltration and potential recharge from precipitation. From a groundwater OU perspective, vadose zone stratigraphy is important in identifying pathways and future risks to groundwater.

As previously stated, the overlying vadose zone solely or mostly consists of sediments of the Hanford formation and Cold Creek unit within the 200-BP-5 Groundwater OU boundary. The Ringold Lower Mud Unit occurs in the vadose zone to the east of B Pond, within sub-areas #7 and #8. The basalt surface occurs above the water table in parts of sub-areas #1, #2, #3, #4, #7, #8, and #9 (Figure 2-1). Areas where the basalt and the Ringold Lower Mud Unit rise above the water table are considered no-flow boundaries for the unconfined aquifer. As the water table declines, the basalt occurrences above the water table enlarge. Vadose zone contamination moving downward encounters the surface of the uppermost basalt bedrock and may migrate downslope and encounter the water table.

Vadose zone stratigraphy and sediment characteristics are of particular interest in the vicinity of the WMA-B/BX/BY Tank Farm and the BY Cribs due to the number of known and potential contaminant sources. The Hanford formation in this vicinity ranges from about 43 to 73 m (140 to 240 ft) in thickness and consists of a series of massive sands intercalated with beds of sand and gravelly sands, and thinner lens of silts and clayey silts (RPP-23748). The Hanford formation in this area can be subdivided into H_3, H_2, and H_1. The contacts between the gravelly units and the sandy units are marked by sharp changes in total natural-gamma radiation, making it simple to distinguish the three facies.

The occurrence of low-permeability layers within the Hanford formation is known to influence the movement of vadose zone contamination in the area of the WMA-B/BX/BY Tank Farm and the BY Cribs. In particular, lateral migration of U-238 detected in the vadose zone at wells 299-E33-45 and 299-E33-41 was assumed to be from contaminated soils associated with tank 241-BX-102. Lateral spreading was attributed to a low-permeability silt zone located on top of the H_3 unit. This lateral migration of contaminants in the vadose zone could occur along a series of silty horizons, with the contaminants later encountering different low-permeability horizons as lateral migration continued.

3.3.1.1 Data Needs Related to Vadose Zone Stratigraphy

Four primary data needs have been identified related to vadose zone stratigraphy in the 200-BP-5 Groundwater OU:

- Depth and possible lateral extent of significant low-permeability layers in the Hanford formation in the vicinity of the WMA-B/BX/BY Tank Farm and the BY Cribs, as well as other areas where contaminant sources pose a significant risk to groundwater quality
- Identification of soil characteristics, including soil geochemistry, of key strata in the vadose zone to aid in modeling potential future contaminant migration/impacts
- Locations of preferential flow of contaminants through the vadose zone via boreholes and ineffectively sealed or unsealed older wells

- Nature and extent of deep vadose zone contamination in the vicinity of the WMA-B/BX/BY Tank Farm and the BY Cribs.

3.3.2 Groundwater Flow

The magnitude and direction of groundwater flow is controlled mostly by the K_h distribution within the aquifer, effective porosity, geometry of the water table or confined aquifer potentiometric surface, and the shape of the aquifer and no-flow boundaries. These parameters are important for describing and modeling the direction and velocity of groundwater flow. Advection is the dominant transport mechanism in non-stagnant aquifers, while diffusion is the dominant transport mechanism where groundwater is stagnant or is moving extremely slowly.

The hydrogeologic setting, including general stratigraphy and groundwater systems within the 200-BP-5 Groundwater OU, was summarized in Section 2.2. The RIs primarily will focus on the unconfined aquifer where the majority of contamination occurs (between the water table and the surface of the Elephant Mountain Member basalt). This aquifer also represents the most likely pathway for potential exposure to groundwater contamination. The Ringold confined aquifer occurs locally in the vicinity of sub-areas #6 and #7, beneath the Ringold Lower Mud Unit. The Rattlesnake Ridge interbed confined aquifer is the most substantial and widespread confined aquifer within the 200-BP-5 Groundwater OU. Contamination in the confined aquifer system is possible only by intercommunication with the unconfined aquifer via well casing or eroded windows in the basalt aquitard.

During plant operations, large volumes of liquid effluent were disposed at various waste sites overlying the 200-BP-5 Groundwater OU (see Section 2.3), imposing measurable groundwater gradients (e.g., water table mounding). The water table generally has been declining following the decrease in liquid effluent discharges to the soil in the 200 East Area. This decline has resulted in extremely flat groundwater gradients across the OU, which makes it difficult, if not impossible, to determine the direction of groundwater flow from water table contour maps (Figure 2-5).

Several techniques have been used recently to evaluate the direction of groundwater flow in the 200-BP-5 Groundwater OU. These techniques consisted of examination and interpretation of water table maps, plume and contaminant trend plots, water-level trend surface analysis, water-level hydrographs for multiple wells, and in situ flow measurements at groundwater wells. Although these techniques have been applied extensively in an effort to understand the direction of groundwater flow, particularly in the vicinity of the WMA-B/BX/BY Tank Farm and the BY Cribs (sub-areas #3 and #4), flow direction in some areas is still uncertain.

A set of water-elevation measurements was collected in July 2005, when the variation in barometric pressure was minimal. The map elevation contours suggest that there is a general low in water elevation trending in a northwest-southeast direction across the 200 East Area, which is consistent with the geometry of contaminant plumes in the region and with the trend of high-permeability aquifer sediment. However, significant uncertainty because of possible errors besides barometric pressure effects, in particular borehole deviations from vertical, makes interpretation of water-level measurement results somewhat tenuous. An ongoing effort to provide corrections to borehole deviation error will continue. These activities may allow for a more detailed interpretation of water-level information to be presented.

One conceptual model for groundwater flow in sub-areas #3 and #4 concludes that groundwater currently enters the vicinity of the 200 East Area from the west, then divides and flows along two separate paths: one pathway is to the southeast, and one pathway to the northwest across a buried anticline and through the gap between Gable Butte and Gable Mountain (sub-areas #2 and #3). The location of the flow divide depends on the relative ability of each pathway to transmit water. The more water that can be transmitted across the buried anticline and through the Gable Gap, the farther southeast will be the divide; the less water that can be transmitted, the farther northwest the divide.

Southeasterly groundwater flow south of the WMA-B/BX/BY Tank Farm and the 216-B-63 Trench generally is accepted and appears to be a direct result of the receding influence of the groundwater mound associated with the B Pond. Likewise, farther to the north in sub-area #3 (Figure 2-9), west of dry well 699-50-53A, groundwater flow appears to be northerly. In DOE/RL-95-59, it was assumed that the center of the Tc-99 plume was located near well 699-50-53A, where high levels of Tc-99, nitrate, cyanide, and Co-60 were found in the late 1980s. Risk analysis modeling was completed for Tc-99 through the year 2018, and the results indicated that the plume center (estimated 7,843 pCi/L) should move 2,682 m (1.7 mi) north of well 699-50-53A. The model assumed a northerly flow rate toward the river of 0.328 m/day, resulting in concentrations exceeding the maximum contamination level (MCL) reaching the Columbia River. Although recent Tc-99 groundwater results indicate that contamination (approximately 2,100 pCi/L) is only reaching as far as well 699-53-55 (located approximately 1,000 m [3,280 ft] northwest of well 699-50-53A), the groundwater appears to be moving north slower than modeled.

Because of the potential for migration of contaminants from the overlying unconfined aquifer, the Rattlesnake Ridge interbed confined aquifer also is monitored in the 200-BP-5 Groundwater OU. The basalt north of the 200 East Area was significantly eroded by late Pleistocene flooding, which may facilitate aquifer intercommunication. Discharge to overlying or underlying aquifers in the vicinity of the Gable Butte/Gable Mountain structural area, for example, may occur through erosional windows in the basalt where removal of the Elephant Mountain Member basalt has left a region of intercommunication between the Rattlesnake Ridge interbed aquifer and the unconfined aquifer. The magnitude and extent of the window through the Elephant Mountain Member is not known. Wells 699-55-60A and 699-53-55C, located in sub-area #3, appear to have encountered the Rattlesnake Ridge interbed directly below the Hanford formation (DOE-RL-2005-76, *Sampling and Analysis Plan for Calendar Year 2005 Well Drilling at the 200-BP-5 Operable Unit*).

3.3.2.1 Data Needs Related to Groundwater Flow

The following two primary data needs have been identified related to groundwater flow in the 200-BP-5 Groundwater OU.

- Determining groundwater flow direction in the unconfined aquifer is difficult to determine, particularly in sub-areas #3 and #4, because of essentially flat gradients.

Definition of groundwater flow direction will aid in evaluating potential future risks from the groundwater plumes in this vicinity. Groundwater flow direction also is necessary to properly evaluate remedial alternatives and to facilitate remedial design. However, if this is not defined during the RI process, more conservative remedial alternatives may be required, which could be used to impose a flow direction.

- Identifying potential migration of contaminants from the overlying unconfined aquifer in the vicinity of old wells (e.g., 299-E33-12, located in sub-area #4) or eroded windows through the uppermost basalt aquitard (e.g., near wells 699-55-60A and 699-53-55C in sub-area #3).

3.3.3 Contaminant Transport

A sufficiently detailed examination of the lithology, structure, hydraulic parameters, and historic artificial recharge of the unconfined aquifer within the 200-BP-5 Groundwater OU is expected to yield an adequate model of groundwater movement in terms of flow vectors, mass transport, and preferential flow paths. Developing a transport model for contaminants in the groundwater requires evaluation of additional parameters that are superimposed upon the geologic and hydraulic factors that govern water movement. The most important of these additional parameters are as follows:

- Point of entry of contaminants into the aquifer (i.e., plume origin)
- Mechanisms that retard the mobility of contaminants relative to groundwater movement
- Mechanisms that remove contaminants (e.g., radioactive decay and chemical degradation)
- Lateral, transverse, and vertical dispersion.

Uncertainties exist regarding contaminant mobility, dispersion, and fate. The program of field testing, sampling, and analysis described in this work plan includes the following general objectives that will address some of the uncertainties and that will provide "ground-truth" information useful for improving predictive computer modeling.

- Determine the three-dimensional distribution of groundwater contaminants and hydraulic flow parameters using depth-discrete sampling and analysis and depth-discrete hydrologic testing.

- Apply single-well geochemical tracer methods or alternative instrumental methods to map K_h (and relative flow velocity) in monitoring wells.

- Use geophysical methods to map the conductive moisture and/or salt zones possibly associated with contaminant plumes at waste disposal sites.

The testing program also will provide the data needed to (1) develop an estimate of the current environmental risk posed by contaminants within the OU, and (2) perform an evaluation of available remedial methods in terms of achievable risk reduction and realistic economics. Specifically, the testing program will serve as the basis for engineering evaluation in the following ways:

- Identifying significant preferential groundwater and contaminant flow paths, which is critical for determining where engineered remedial solutions would be most effectively applied

- Performing depth-discrete profiling of the contaminant burden of the groundwater, which is critical for determining the design scale for engineered remedial solutions, evaluating various treatment technologies, and performing realistic cost/benefit calculations

- Performing depth-discrete profiling of hydraulic parameters, which is necessary to predict the hydraulic response of contaminated intervals of the aquifer to pumping and injecting of water for collecting, treating, or isolating contamination

- Performing vertical profiling and flow-mapping, which together provide the means to estimate the rate of groundwater and contaminant mass transport, which is yet another factor affecting design scale, and which is necessary for environmental risk assessment (e.g., risk associated with downgradient transport of contaminants).

The foregoing summary applies to contaminants that already have reached the groundwater. For waste sites overlying the 200-BP-5 Groundwater OU that have contributed to groundwater contamination, or which may do so in the future, it is worthwhile to consider some of the factors that control the transport of liquid wastes through the soil column from the surface to the groundwater and that frustrate development of quantitative vadose zone flow models.

For example, consider the simple conceptual flow model for vadose zone transport of liquid wastes disposed to cribs. The model assumes that infiltration of the liquid waste is evenly distributed over the active surface of the crib, that flow vectors are vertically downward-modified by limited lateral spread above less permeable strata, and that contaminants enter the groundwater geographically below the crib. This model, along with estimates of the total pore volume in the vadose zone directly beneath individual liquid waste sites, has been used to evaluate the likelihood that the wastes have migrated to the water table (DOE/RL-92-19). The assumption inherent in that evaluation was that the liquid wastes would reach the groundwater only after the volume of waste disposed to a site exceeded the pore space beneath the site. Both the model and the pore volume estimate that depends upon it have the following significant shortcomings.

- No allowance is made for possible channeling along wells or other preferential pathways.

- The model does not account for possible stratigraphic control of lateral flow (e.g., by relatively impermeable strata).

- The method for estimating the pore space is unclear.

- Total pore volume, particularly in coarse sediments, is likely to be significantly greater than sediment specific retention. This model is likely to over-predict the retention of liquid wastes in the vadose zone.

In view of these problems, it is clear that neither the bulk quantity nor vertical position of liquid wastes retained in the vadose zone can be confidently estimated from site geometry, depth to groundwater, and disposal history.

As with aquifers, aqueous transport of contaminants through the vadose zone is affected by mechanisms that retard, remove, or degrade contaminants. However, predicting contaminant mobility (e.g., based on K_d) for vadose zone transport is far more difficult than for aquifer transport. Some of the major complications are as follows.

- The general direction of transport is through (rather than along) individual strata, so sediment characteristics that affect retardation can change considerably along the flow path. This effect can be seen easily in spectral-gamma logging system surveys from boreholes, where radionuclides (e.g., uranium and cesium) are found to be concentrated at discrete elevations.

- Significant moisture fronts may be associated with a component of lateral flow when encountering a low permeability soil horizon. How laterally extensive is the resultant moisture front and is the vertical extent of the moisture front representative from the borehole are uncertain.

- Retardation mechanisms are affected by water chemistry, but the major-ion chemistry of disposed wastes can be considerably different from "typical" Hanford Site groundwater used in the laboratory for estimating K_d (RPP-7884, *Field Investigation Report for Waste Management Area S-SX*).

- Contaminant concentrations in disposed wastes are relatively high, not having been diluted. Thus, contaminant species can compete with one another for sorption or cation-exchange sites on mineral surfaces. Also, contaminants may be present in concentrations that effectively overwhelm sorption on exchange sites (RPP-7884).

Data Needs Related to Contaminant Transport. Physical and geochemical sediment properties affecting aqueous-phase contaminant transport need to be better defined in key strata within the vicinity of the WMA-B/BX/BY Tank Farm and the BY Crib area (sub-area #4). This information is important for modeling emerging contamination from the vadose zone, identifying the specific source(s) of uranium and Tc-99 in that area, and supporting predictive modeling of groundwater contamination.

3.4 CONTAMINANT PLUMES

This section describes the presence and distribution of groundwater contaminants exceeding drinking water standards (DWS) in the 200-BP-5 Groundwater OU. Although the focus in this section is on current contaminants exceeding the DWS, several other COPCs were identified in WMP-28945 and are presented in the SAP (Appendix A). Groundwater contaminant plume descriptions were reported in PNNL-15670 and are reproduced in this discussion for current distribution of groundwater contamination as currently understood for the 200-BP-5 Groundwater OU. On an annual basis, the Hanford Site groundwater-monitoring reports provide a compilation of monitoring conducted for RCRA TSD units, CERCLA investigations, AEA requirements, and special investigations. Note that these descriptions are augmented as relevant, with more recently collected data. Also, the COCs as defined in the fiscal year (FY) 2005 annual report (PNNL-15670) differ slightly from those determined during the 200-BP-5 Groundwater OU DQO process (WMP-28945), which is discussed later in this section.

In 2005, monitoring was conducted as follows:

- RCRA TSD unit monitoring
  - Twenty-five wells are sampled quarterly to semiannually at the WMA-B/BX/BY Tank Farm.
  - Twelve wells are sampled quarterly to semiannually at the 216-B-63 Trench.
  - Seventeen wells are sampled semiannually at LLWMA-1.
  - Eleven wells are sampled semiannually at LLWMA-2.
  - Two wells are sampled semiannually at the LERF.
  - Nine wells are sampled quarterly at the WMA-C Tank Farm.
  - All RCRA wells were sampled as scheduled, with the exception of two wells at the WMA-B/BX/BY Tank Farm.
- CERCLA and AEA monitoring
  - Wells are sampled annually and triennially for COPCs and supporting parameters in the uppermost aquifer.
  - Six guard wells are sampled annually at Gable Gap.
  - Additional wells are sampled triennially in the Rattlesnake Ridge interbed confined aquifer.
  - Sampling of one well was delayed until October 2005 because of scheduling constraints; all other wells were sampled as scheduled in 2005.

Contamination of groundwater in the 200-BP-5 Groundwater OU is widespread in the unconfined aquifer. Numerous chemical and radiological contaminants have been detected in monitoring wells for decades. Contamination in the Rattlesnake Ridge interbed confined aquifer is known to occur, but the extent is not known due to the limited distribution of wells monitoring the Rattlesnake Ridge interbed confined aquifer.

For purposes of defining preliminary contaminant boundaries, contaminant plumes are considered to consist of those groundwater contaminants that exceed DWSs using EPA's MCLs. For those contaminants where MCLs have not been set by EPA, calculated MCLs were generated during the DQO process for WMP-28945 using EPA's derived DWS for radionuclides based on a 15 pCi/L or 4 mrem/yr dose standard using maximum permissible concentrations in water specified in NBS Handbook 69, *Maximum Permissible Body Burdens and Maximum Permissible Concentrations of Radionuclides in Air or Water for Occupational Exposure*. Note that the 4 mrem/yr dose standard is not applied to individual radionuclides but the sum of all the radionuclides in a particular area. However, for preliminary identification, individual radionuclides were identified where the 4 mrem/yr dose standard was exceeded. Both MCLs and calculated MCLs are referred to as DWS in this work plan.

Table 3-1 lists the contaminants that exceed current DWSs within the 200-BP-5 Groundwater OU (WMP-28945). It should be noted that Co-60 is included in this list even though it was not included in WMP-28945 because of recent increases. The presence of Co-60 is limited to a few wells beneath the northern portion of the BY Cribs and because of the limited areal exposure is not present in a map like those contaminants below. Likewise, sulfate has exceeded the DWS in isolated wells (one well under the northern BY Cribs and one in the southeast area of LLWMA-2) and, due to the limited areal extent, is not mapped in this report. The identified plumes for the contaminants exceeding current DWS are listed below, provided in the plate map, and provided in Chapter 5.0 sub-area figure maps.

This report visually presents contaminants that exceed MCLs over a defined areal extent. Note that some contaminants have larger areas because of the duration and mobility within the groundwater. It is important to understand that declining water elevations and uncertainty in groundwater gradient in some areas may cause certain plumes to reflect a past groundwater flow condition which may have changed either in flow rate or even possibly direction. Descriptions of these plumes are described in the following subsections. Names of the individual plumes are as follows:

- Tritium (20,000 pCi/L – MCL):
  - North of Gable Gap to Columbia River tritium plume
  - Gable Gap tritium plume
  - BY Cribs tritium plume
  - B Plant area cribs tritium plume (200 East Area plume)
- Uranium (30 µg/L – MCL):
  - BY Crib/WMA-B/BX/BY Tank Farm and extending to the northwest corner of LLWMA-1 uranium plume
  - 216-B-5 Reverse Well uranium plume
  - 216-B-12/216-B-62 Cribs uranium plume
- Iodine-129 (1 pCi/L – EPA 4 mrem/yr dose standard):
  - Gable Gap I-129 plume
  - 200 East Area I-129 plume (extends across the northeastern half of the 200 East Area, B Pond sub-area, and eastward into the 200-PO-1 Groundwater OU)
- Technetium-99 (900 pCi/L – EPA 4 mrem/yr dose standard):
  - BY Cribs and the WMA-B/BX/BY Tank Farm Tc-99 plume
  - WMA-C Tank Farm Tc-99 plume
- Cyanide (200 µg/L – MCL):
  - BY Cribs cyanide plume
- Strontium-90 (8 pCi/L – EPA 4 mrem/yr dose standard):
  - Gable Mountain Pond Sr-90 plume
  - 216-B-5 Reverse Well Sr-90 plume
- Cesium-137 (200 pCi/L – EPA 4 mrem/yr dose standard):
  - 216-B-5 Reverse Well Cs-137 plume

- Plutonium-239/240 (15 pCi/L – EPA DWS):
  - 216-B-5 Reverse Well Pu-239/240 plume
- Nitrate (45 mg/L as NO_3 – MCL):
  - BY Cribs and the WMA-B/BX/BY Tank Farm nitrate plume
  - Gable Mountain Pond nitrate plume
  - LLWMA-1 nitrate plume
  - the WMA-C Tank Farm nitrate plume
  - B Pond sub-area nitrate plumes (multiple, minor plumes).

3.4.1 Tritium Plumes

Tritium contamination is widespread throughout the northwest portion of the 200 East Area. Tritium is not significantly affected by chemical processes and, therefore, acts as a nonreactive or conservative tracer. The contamination extends north through the gap between Gable Mountain and Gable Butte and to the Columbia River, as well as southeast through the 200-PO-1 Groundwater OU. Numerous sources of tritium were introduced to the groundwater over greatly varying flow conditions. Tritium contamination within the 200-BP-5 Groundwater OU has declined greatly because of natural decay (half-life of tritium is 12.3 years) and dispersion.

3.4.1.1 North of Gable Gap to Columbia River Tritium Plume (Sub-Area #1)

Tritium concentration in well 699-64-62 (18,600 pCi/L) increased slightly in FY 2006; however, values have been trending downward over the past decade. Well 699-72-73, located between the 100-B/C and 100-K Areas, exceeded the DWS in FY 2001, but tritium concentrations have subsequently declined, and a value of 17,700 pCi/L was reported in FY 2006.

3.4.1.2 Gable Gap Tritium Plume

Tritium at levels above the DWS can be found between Gable Mountain and Gable Butte in sub-area #2, indicating a preferential flow pathway through Gable Gap. Concentrations in monitoring wells 699-61-62 and 699-60-60 in Gable Gap increased slightly, with measured values for FY 2006 of 21,300 pCi/L and 25,850 pCi/L, respectively.

3.4.1.3 Waste Management Area B/BX/BY Tank Farm and BY Cribs Tritium Plume

Tritium values increased for several years at the south end of the WMA-B/BX/BY Tank Farm but may be starting to decline. The maximum tritium value in this region in FY 2004 was 19,900 pCi/L in well 299-E33-21, but a value of 13,700 pCi/L was reported in the second half of FY 2006.

3.4.1.4 B Plant Area Cribs Tritium Plume (200 East Area Plume)

Wells in the vicinity of the 216-B-5 Injection Well had concentrations of tritium below the DWS in FY 2005. The tritium plume is spreading southeastward through the 200-PO-1 Groundwater OU.

3.4.2 Uranium Plumes

Multiple sources are attributed to the uranium groundwater contamination in the 200 East Area. Uranium contamination in the 200-BP-5 Groundwater OU is limited to monitoring wells in three isolated areas: the WMA-B/BX/BY Tank Farm and the BY Cribs and stretching to the northwest corner of the LLWMA-1, near the 216-B-5 Injection Well, and at the 216-B-62 Crib. Groundwater uranium concentrations in all three areas exceed the DWS of 30 µg/L.

3.4.2.1 BY Cribs and Waste Management Area B/BX/BY Tank Farm Uranium Plume

The primary source of currently increasing uranium values in 200-BP-5 Groundwater OU groundwater is the WMA-B/BX/BY Tank Farm. The conclusion that tank farm uranium contamination is currently the primary source is based on geophysical logging data, isotopic analysis, and comparison of Stiff diagrams using major-ion chemistry. The most likely explanation for the location of the apparent core of the uranium plume is that uranium solutions from the tank 241-BX-102 overfill event likely migrated with a significant degree of lateral movement through sections of the vadose zone before reaching the water table. This area has reported the highest uranium concentrations for the 200-BP-5 Groundwater OU during the last several years. The primary source is currently considered to be the tank 241-BX-102 overfill event. This is based on both the geophysical logging data showing a cluster of high uranium readings in boreholes adjacent to the BX Tank Farm and isotopic analysis showing similarities between uranium ratios in the groundwater plumes and the tank 241-BX-102 overfill event (PNNL-14187, *Hanford Site Groundwater Monitoring for Fiscal Year 2002*). The contamination is present in a narrow northwest-southeast band. It should be noted, however, that the BY Cribs have been reported with a sizeable inventory of uranium and may be a source of groundwater contamination. The BY Cribs also may have been a potential source of uranium in the past based on uranium concentrations reported in wells beneath this site. It is unknown what type of isotopic signature the uranium disposed to the BY Cribs has at this time. Therefore, this waste site, although not attributed to deep uranium based on geophysical logs, is still considered a potential source for past releases and possibly current and future releases.

Uranium concentrations have been increasing in well 699-49-57A in the last several years (15.4 µg/L reported in FY 2006). This may suggest that the plume is migrating to the northwest toward the Gable Gap area; however, uranium concentrations of this magnitude have been detected in proximal wells during the 1990s. In addition, recent analytical results at wells 699-50-48A and 699-50-56 (Figure 5-2) have been reported with elevated uranium in fine-grained sediments above the aquifer that do not match the tank 241-BX-102 isotopic uranium signature. Thus, infiltration from similar vadose zone-contaminated sediments near well 699-49-57A may be the reason for increasing uranium concentrations. In FY 2006, the maximum reported uranium concentration for a single sample in this well was 16.8 µg/L.

3.4.2.2 216-B-5 Reverse Well Uranium Plume

Uranium contamination is associated with the Cs-137, plutonium, and Sr-90 groundwater contamination found at the former 216-B-5 Injection Well. The highest uranium concentration detected in FY 2006 at this site was 96 µg/L in well 299-E28-23, located approximately 1 m (3.3 ft) from the injection well. Uranium concentrations are roughly stable in well 299-E28-23.

Uranium values were significantly lower in wells 299-E28-24 (20.2 μg/L) and 299-E28-25 (17.1 μg/L), located 7 m (23 ft) southeast and 7 m (23 ft) northwest from the injection well, respectively. During FY 2006, a uranium value of 37.0 μg/L was reported for well 299-E28-6, located 343 m (1,125 ft) south of the injection well. Uranium concentrations have been generally declining to stable in well 299-E28-6. It has not been confirmed that the source of uranium contamination in this well is the 216-B-5 Injection Well.

3.4.2.3 B-12/B-62 Cribs Uranium Plume

Uranium was detected consistently at levels slightly above the DWS (30 μg/L) in wells monitoring the 216-B-62 Crib, located northwest of the B Plant. Uranium concentrations were more than 200 μg/L in the mid-1980s but declined to current levels by the early 1990s. The maximum FY 2006 uranium concentration at the 216-B-62 Crib was 37.4 μg/L, reported for well 299-E28-18. Uranium concentration levels between 15 and 18 μg/L have been found along the western side of LLWMA-1, but no wells exceeded the DWS in FY 2006. The uranium detected near LLWMA-1 may have originated at the 216-B-62 Crib or its predecessor, the 216-B-12 Crib.

3.4.3 Iodine-129 Plumes

Iodine-129 contamination is present throughout the 200-BP-5 Groundwater OU. The I-129 plume covers an area from the Gable Mountain/Gable Butte Gap to, and extending through, the 200-PO-1 Groundwater OU. Levels greater than the DWS (1 pCi/L) have not passed beyond the gap between Gable Mountain and Gable Butte. A region of elevated I-129 concentrations (approximately 5 pCi/L) has been present in the WMA-B/BX/BY Tank Farm, but wells in this area reported less than 5 pCi/L during FY 2006. Interpretation of the I-129 configuration in this area is complicated by elevated detection limits that result from laboratory analytical issues. In addition, the current laboratory reporting system produced some values reported as not detected at levels greater than the DWS (1 pCi/L).

3.4.4 Technetium-99 Plumes

Considerable uncertainty exists regarding the extent of Tc-99 contamination. Technetium-99 was not routinely measured in groundwater before the late 1980s, which limits the information on historical trends; in addition, well coverage is limited. A plume of Tc-99 extends from the area of the BY Cribs well into sub-area #3, north of the 200 East Area. The plume has moved through Gable Gap at levels below the DWS.

3.4.4.1 BY Cribs and Waste Management Area B/BX/BY Tank Farm Technetium-99 Plume

A Tc-99 plume covers the area from the southern portion of the WMA-B/BX/BY Tank Farm to the northwest. A significant portion of the plume is north of the 200 East Area boundary and may represent early releases of Tc-99 from the BY Cribs (PNNL-13080); however, near-field Tc-99 may have been contributed by tanks or other cribs. Detection of Tc-99 at levels lower than the DWS (900 pCi/L) in sub-areas #1 and #2 indicates that this radioisotope has historically moved north into and through Gable Gap.

In the late 1990s, increasing Tc-99 concentrations were seen in the BY Crib area in wells 299-E33-7 and 299-E33-38 (Figure 5-3). In early 1999, trends for both wells began to track together and reached an apparent maximum in late 2000. These trends are believed to reflect the relatively recent breakthrough of contamination from the vadose zone into the saturated zone near the BY Cribs. In particular, high concentrations of Tc-99 in well 299-E33-38 (average of 17,200 pCi/L in FY 2006) and well 299-E33-4 (average of 42,900 pCi/L in FY 2006) suggest a continuing source of contamination from the vadose zone to groundwater. A general correlation of concentration trends for Tc-99, nitrate, Co-60, iron, and cyanide in wells 299-E33-7 and 299-E33-38 and local distribution of these constituents indicates that the primary source of Tc-99 contamination was related to past discharges of ferrocyanide-containing waste to the BY Cribs (PNNL-13080; PNNL-14049, *Data Quality Objectives Summary Report – Designing a Groundwater Monitoring Network for the 200-BP-5 and 200-PO-1 Operable Units*).

3.4.4.2 Waste Management Area C Tank Farm Technetium-99 Plume

Technetium-99 is detected in wells monitoring the WMA-C Tank Farm. Because groundwater flow directions are difficult to determine here due to the flat gradient of the water table, the source of the contaminants is under investigation. Analysis of anions and technetium ratios suggests that tanks or UPRs within the WMA-C Tank Farm may be a localized source of contaminants. Downgradient Tc-99 continued to increase in FY 2006 to more than 3,000 pCi/L. Migration of this Tc-99 plume is interpreted from the northeast to southwest; however, this flow direction is being investigated. The installation of the new well 299-E27-4 in FY 2003 resulted in a groundwater analysis with the highest Tc-99 activity to date. The level dropped from the June 2005 value of 7,070 pCi/L to 3,900 pCi/L in September 2006. The elevated Tc-99 concentrations are found with low levels of nitrate. The ratio of nitrate to Tc-99 at well 299-E27-4 is 2.8, indicating that the source of the contaminated groundwater may be tank-related, which is the same as nearby well 299-E27-13 (PNNL-14187; PNNL-14548). In general, a ratio of nitrate to Tc-99 lower than 10 suggests that the source of contamination for this well may be related to the presence of contaminants in the vadose zone associated with past tank storage liquid waste.

3.4.5 BY Cribs Cyanide Plume

Cyanide is found at levels above the DWS (200 μg/L) and continues to be detected in a number of wells in the 200-BP-5 Groundwater OU. The maximum cyanide concentration in this area in FY 2006 was 1,470 μg/L from well 299-E33-4, located in the northern portion of the BY Cribs (Figure 5-3). Well 299-E33-38, located in the southern portion of the cribs, had a maximum cyanide value of 523 pCi/L in FY 2006. Cyanide contamination trends in wells located at the BY Cribs are similar to those of Tc-99, Co-60, and nitrate and may be related to past discharges of ferrocyanide waste to the BY Cribs (PNNL-13080; PNNL-14049). Cyanide and Co-60 are both found in the groundwater in the vicinity and generally are associated with ferrocyanide waste streams generated by uranium-scavenging operations conducted during the mid-1950s (PNNL-13080; PNNL-14049). These co-contaminants are useful for distinguishing contaminant groups and contaminant sources. Cobalt-60 has a relatively short half-life (5.3 years) and generally is found at levels less than the DWS (100 pCi/L).

3.4.6 Strontium-90 Plumes

3.4.6.1 Gable Mountain Pond Strontium-90 Plume

In several wells near Gable Mountain Pond, Sr-90 concentrations rose in the 1990s and have declined since 2000 but remain above the DWS. Strontium-90 at Gable Mountain Pond (well 699-53-47A) in FY 2000 was greater than 1,000 pCi/L but has been declining in recent years (679 pCi/L in FY 2006). Well 699-53-48A sampling indicated an apparent decrease in Sr-90 in FY 2006, with a reported value of 398 pCi/L versus a value of 741 pCi/L in FY 2005.

3.4.6.2 216-B-5 Reverse Well Strontium-90 Plume

Strontium-90 has relatively low mobility and generally is found near the source. Several wells near the 216-B-5 Injection Well have elevated concentrations of Sr-90. Four wells (299-E28-2, 299-E28-23, 299-E28-24, and 299-E28-25) had concentrations of Sr-90 above the DWS (8.0 pCi/L) in FY 2006. The highest Sr-90 concentration was reported for well 299-E28-23, with a value of 3,390 pCi/L in FY 2006. Groundwater sampled for Sr-90 in well 299-E28-25 was reported to have an activity level of 2,040 pCi/L in FY 2006.

3.4.7 216-B-5 Reverse Well Cesium-137 Plume

Cesium-137 has relatively low mobility and generally is found near the source. Well 299-E28-23 is approximately 1 m (3.3 ft) from the 216-B-5 Injection Well and consistently has had concentrations of Cs-137 greater than the DWS (200 pCi/L). In FY 2006, a value of 891 pCi/L for Cs-137 was reported for this well. All other wells sampled at this site had Cs-137 concentrations below the DWS in FY 2006.

3.4.8 216-B-5 Reverse Well Plutonium-239/240 Plume

Plutonium-239 and Pu-240 were detected in past years in samples taken from several wells near the 216-B-5 Injection Well. Plutonium is relatively immobile and, therefore, is found in the aquifer only near the injection well. The highest reported plutonium concentration in FY 2006 was at well 299-E28-23, which had a filtered value of 7.78 pCi/L and an unfiltered value of 18.6 pCi/L. Note that the EPA's DWS for Pu-239 is 15 pCi/L and 1.2 pCi/L for the EPA 4 mrem/yr dose standard. The generally lower concentration in filtered versus unfiltered samples suggests that a portion of the plutonium in contaminated groundwater is associated with particulates. The concentration of plutonium in well 299-E28-23 has not exhibited a clear change in trend in recent years.

3.4.9 Nitrate Plumes

A nitrate plume originating in the 200 East Area extends beyond the boundary fence line northwest toward the Columbia River and, like tritium, acts as a tracer delineating a pathway through Gable Gap. Detailed contour plots presented in annual reports (PNNL-15670) show that the nitrate plume beneath the 200 East Area has three parts: (1) a west plume that extends beneath the western portion of LLWMA-1, (2) an east plume extending from the BY Cribs and surrounding cribs toward the northwest, and (3) a southern plume extending beneath the southern portion of the BY Cribs and surrounding cribs to the south. The northwest extent of the nitrate plume extends through the gap between Gable Butte and Gable Mountain to the Columbia River at levels less than the DWS (45 mg/L). The outer edge of the mapped nitrate plume is delineated in the plate map and other figures at 20 mg/L, which is less than half of the DWS.

3.4.9.1 Low-Level Waste Management Area 1 Nitrate Plume

The western portion of the nitrate plume, extending beneath the west portion of LLWMA-1, appears to be part of a larger plume extending primarily from the PUREX facility in the 200-PO-1 Groundwater OU. This plume apparently moved to the northwest under past flow conditions during the period of high discharge to 200 East Area facilities and the B Pond.

3.4.9.2 BY Cribs and Waste Management Area B/BX/BY Tank Farm Nitrate Plume

The highest nitrate concentrations are in the vicinity of the BY Cribs and the 216-B-8 Crib. High concentrations of nitrate are associated with the Co-60, cyanide, and Tc-99 plumes originating from the BY Cribs (PNNL-13080). The highest nitrate concentrations measured in FY 2006 were found in well 299-E33-4 (3,200 mg/L), near the BY Cribs (Figure 5-3). This well is almost dry and may be nearly representative of conditions from the vadose zone based on limited groundwater dilution. The highest value for nitrate associated with the 216-B-8 Crib during FY 2006 was a concentration of 881 mg/L reported for well 299-E33-16.

3.4.9.3 Gable Mountain Pond Nitrate Plume

Nitrate continued to be detected in wells monitoring the Gable Mountain Pond area (located in sub-area #8) at levels above the DWS. In FY 2006, a nitrate value of 88 mg/L was measured in well 699-53-47A and a value of 177 mg/L was measured in well 699-53-48A.

3.4.9.4 Waste Management Area C Tank Farm Nitrate Plume

Elevated concentrations of nitrate in the area of the WMA-C Tank Farm suggest tank waste may be a source or may indicate migration of UPRs to the soil at WMA-C.

3.4.9.5 B Pond Sub-Area Nitrate Plumes (Multiple, Minor Plumes)

Delineation of nitrate plumes in this area is tentative, because declining water levels and multiple possible contributing sources complicate definition of specific plumes.

3.4.10 Rattlesnake Ridge Interbed Confined Aquifer Contamination

The Rattlesnake Ridge interbed confined aquifer is affected much less from contamination than the overlying unconfined aquifer system. Contamination found in the Rattlesnake Ridge interbed confined aquifer most likely attributed to areas where confining units of basalt have been completely eroded and to areas where past disposal of large amounts of wastewater to the vadose zone resulted in downward vertical hydraulic gradients. In some areas, older, poorly sealed monitoring wells (e.g., well 299-E33-12), which penetrated the Rattlesnake Ridge interbed confined aquifer, can provide a downward pathway for contaminant migration. Because of these factors, intercommunication between the aquifers permitted groundwater flow from the unconfined aquifer to the underlying confined aquifer, thereby increasing the potential to spread contamination.

An area of intercommunication between the unconfined and Rattlesnake Ridge interbed confined aquifer systems was first identified in the northern portion of the 200 East Area (RHO-BWI-ST-5, *Hydrologic Studies within the Columbia Plateau, Washington: an Integration of Current Knowledge*; RHO-RE-ST-12P). Several confined aquifer wells north and east of the 200 East Area have shown evidence of intercommunication with the overlying unconfined aquifer (PNL-10817). Intercommunication between the unconfined and confined aquifers in this region has been attributed to erosion of the upper Saddle Mountains Basalt and a downward hydraulic gradient that resulted from groundwater mounding associated with past wastewater disposal to the ground. However, the groundwater mound has diminished in recent years.

Wells completed in the Rattlesnake Ridge interbed confined aquifer system are routinely sampled on the Hanford Site. Most of these wells are sampled every 3 years, and a few are sampled annually. During FY 2003 through FY 2005, 21 samples were collected from 17 wells and analyzed for chemical and radiological constituents. Many of the samples were analyzed for tritium, I-129, and nitrate because these constituents are highly mobile and are widespread in the overlying unconfined aquifer. These constituents would provide an early warning for potential contamination in the Rattlesnake Ridge interbed confined aquifer system. Groundwater samples from the Rattlesnake Ridge interbed confined aquifer also were analyzed for anions (other than nitrate), cations, cyanide, gross alpha, gross beta, gamma emitters, Sr-90, Tc-99, and uranium isotopes. Figure 3-11 depicts the distribution of chemical and radiological constituents in the Rattlesnake Ridge interbed confined aquifer for the period FY 2003 through FY 2005 (PNNL-15670).

In the northern portion of the 200 East Area, Tc-99 was elevated in the Rattlesnake Ridge interbed confined aquifer in one well. The Tc-99 concentration was 1,090 pCi/L in well 299-E33-12 in 2004. However this level, which exceeds the DWS (900 pCi/L), is slightly lower than concentrations in this well in the early 1990s. Contamination in this well is attributed to migration of high-salt waste down the borehole during the period when it was open to both the unconfined and confined aquifers (RHO-RE-ST-12P). This well is located in the vicinity of a Tc-99 plume in the overlying unconfined aquifer (see Section 2.2.2.3 and Figure 2-10).

Cyanide and nitrate also are elevated in the same well (299-E33-12) where Tc-99 is elevated. However, these co-contaminants are at levels that do not exceed their respective DWS.

Concentrations of cyanide and nitrate have not changed significantly at this well since the early 1990s. Like Tc-99, this contamination is associated with migration of high-salt waste down the borehole during well construction when it was open to both the unconfined and confined aquifers (RHO-RE-ST-12P). Cyanide and nitrate are co-contaminants with much higher concentrations in the unconfined aquifer in the northern portion of the 200 East Area.

Nitrate levels in the Rattlesnake Ridge interbed confined aquifer typically range from less than detectable to approximately 1 mg/L across the Hanford Site. Higher levels indicate intercommunication with the overlying contaminated unconfined aquifer (RHO-BWI-ST-5; RHO-RE-ST-12P; and PNL-10817). The majority of wells with higher nitrate in the Rattlesnake Ridge interbed confined aquifer occur near Gable Mountain and the 200 East Area.

Some samples collected from Rattlesnake Ridge interbed confined aquifer wells were analyzed for I-129. These wells are located beneath or near the I-129 plume contained within the overlying unconfined aquifer. Iodine-129 was not detected in the Rattlesnake Ridge interbed confined aquifer during FY 2003 through FY 2005.

3.4.11 Data Needs Related to Groundwater Plumes

Data needed to improve understanding of the nature and extent of 200-BP-5 Groundwater OU groundwater contaminant plumes are as follows.

- Additional monitoring wells are necessary to define contaminant plume extent and geometry (in particular, the uranium and Tc-99 plumes associated with the BY Cribs and the WMA-B/BX/BY Tank Farm contaminant sources and the Tc-99 and nitrate plumes associated with the WMA-C Tank Farm).
- The vertical variations in contaminant concentrations within the unconfined aquifer need to be defined.
- Monitoring the wells in Gable Gap is necessary to serve as a guide for calculating the mass transfer of contaminants north of Gable Gap. As water levels decline, net movement of groundwater north is expected to decline. However, if concentrations of contaminants rise, it will be informative to calculate relative differences in mass transfer. Estimates of groundwater velocity and direction should be calculated for the sampling period for estimating mass transfer of contaminants through Gable Gap.
- Improved definition is necessary of the mapped contaminant plumes in the unconfined aquifer with contouring of values above and below the MCLs in order to observe changes in contaminant concentrations with time.
- The installation of monitoring wells south of wells 299-E33-12 and 699-53-55 is necessary to improve understanding of contaminants detected in the Rattlesnake Ridge confined aquifer, the associated source, and factors affecting contaminant movement.

- Mapping contaminant concentrations within the confined aquifer zones is necessary, including the Ringold confined aquifer and the Rattlesnake Ridge interbed confined aquifer.

3.5 RECEPTOR IDENTIFICATION

Figure 3-12 illustrates the conceptual exposure model for potential ecological and human receptors with respect to the groundwater. The figure also illustrates the association of the overlying sources and vadose zone. The model construct is consistent with the conceptual model published in DOE/RL-98-28, *200 Areas Remedial Investigation/Feasibility Study Implementation Plan – Environmental Restoration Program.*

The first column of the CSM represents primary contaminant sources overlying the 200-BP-5 Groundwater OU. The contaminants were introduced to the environment by surface and subsurface liquid discharges, resulting in contamination of the soil beneath the waste sites (i.e., secondary waste source). Secondary contaminant release occurs through leaching and infiltration. The leaching and infiltration rate is highly dependent on the volume of migrating fluids, the physical and chemical characteristics of the geologic strata, and the chemical makeup of the contaminants. Primary and secondary contaminant releases may result in contamination of the groundwater within the 200-BP-5 Groundwater OU and, ultimately, the groundwater discharge point (i.e., the Columbia River). Potential receptors (human and other biota) may be exposed to contaminated groundwater and surface water through several exposure pathways, including ingestion, dermal contact, and external radiation.

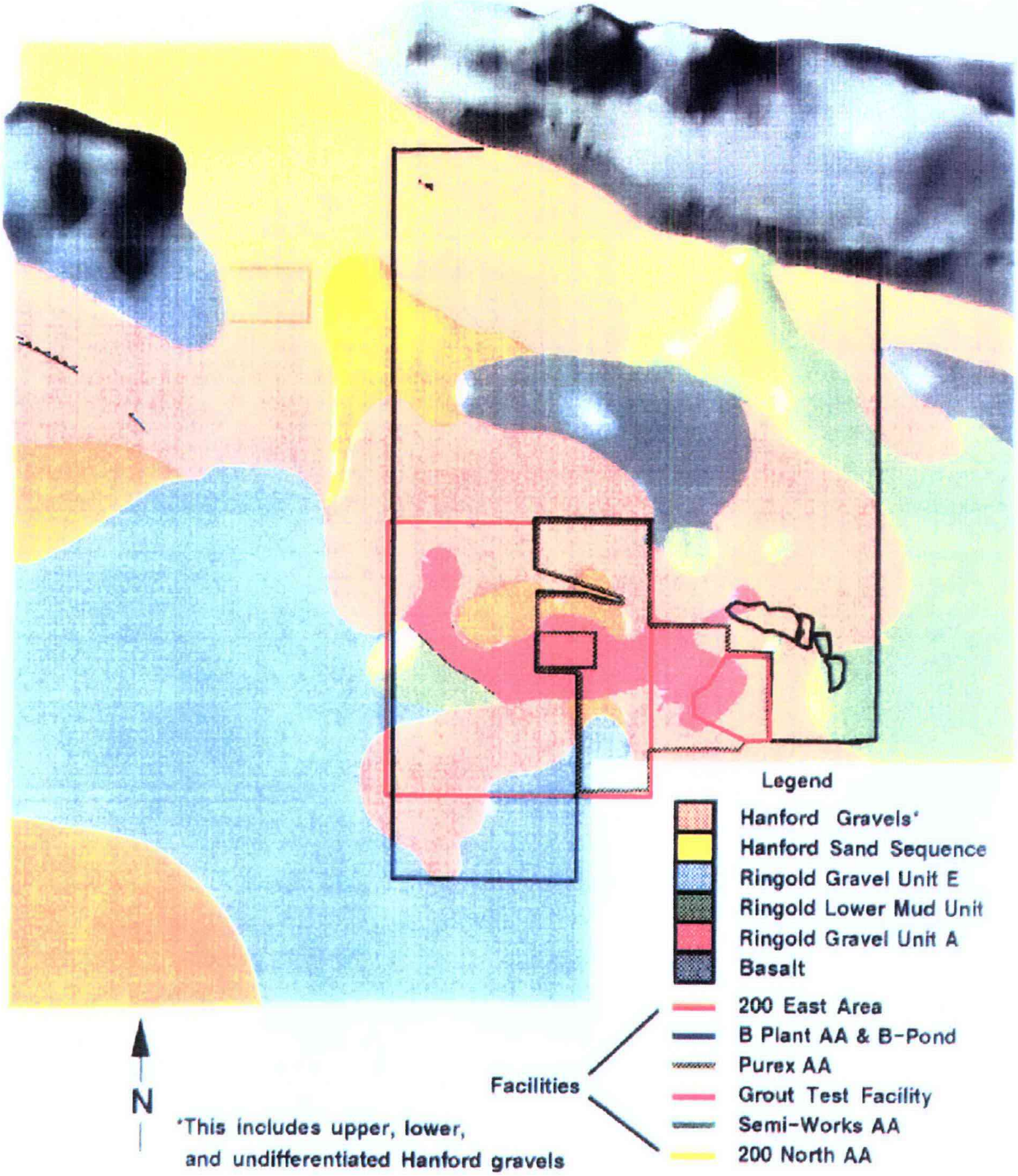
An important criterion for identifying potential receptors is determining the current and reasonably anticipated future land use for the Hanford Site. DOE's intention is to restore the groundwater beneath the Hanford Site to its highest beneficial use. Because the final land use has not been determined, a variety of restricted- and unrestricted-use-exposure scenarios will be evaluated in the baseline risk assessment. Exposure scenarios will include drinking water and other potable water uses for future potential industrial workers, future potential rural residents, and future Native American Subsistence Lifeway receptors. Native American Subsistence Lifeways scenarios include the Confederated Tribes of the Umatilla Indian Reservation, the Yakama Nation exposure scenario, and the Wanapum Lifeways Scenario.

The schematic view of the conceptual exposure model (Figure 3-12) provides a current understanding of the contaminant sources, release mechanisms, environment transport media, potential exposure points, potential routes of exposure, and potential receptor groups associated with the OU. Potential ecological exposure would occur at the Columbia River and West Lake and would include aquatic plants and animals.

3.5.1 Data Needs Related to Receptor Identification

Exposure scenarios for the groundwater within the 200-BP-5 Groundwater OU need to be finalized to allow risk evaluation during the baseline risk assessment.

Figure 3-1. Geologic Units at the Water Table from the Gable Gap and South in 1992.



From DOE/RL-92-19, *200 East Groundwater Aggregate Area Management Study Report.*

Figure 3-2. Isopach Map of the 1992 Hanford Formation Lower Gravel Sequence.

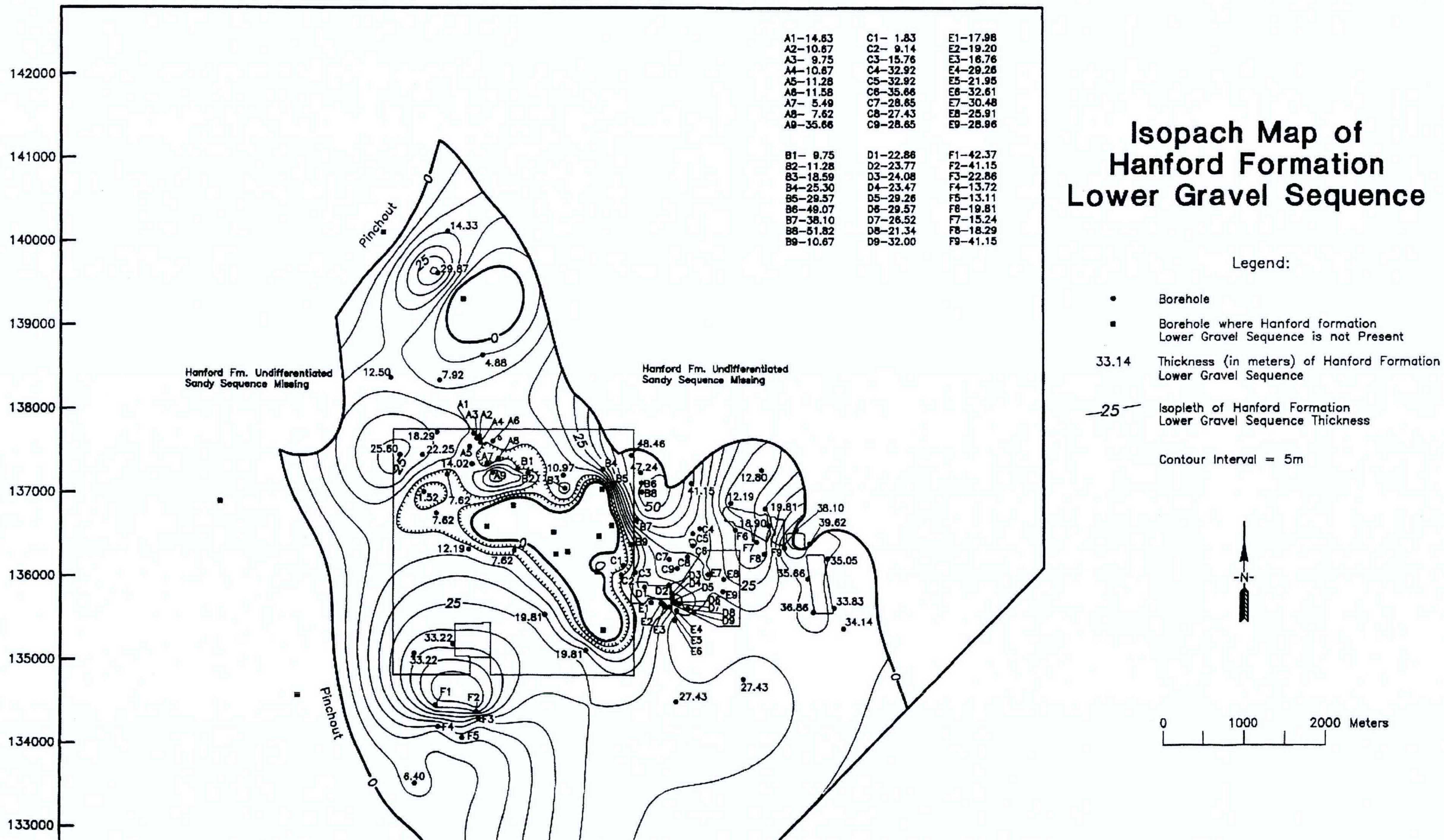
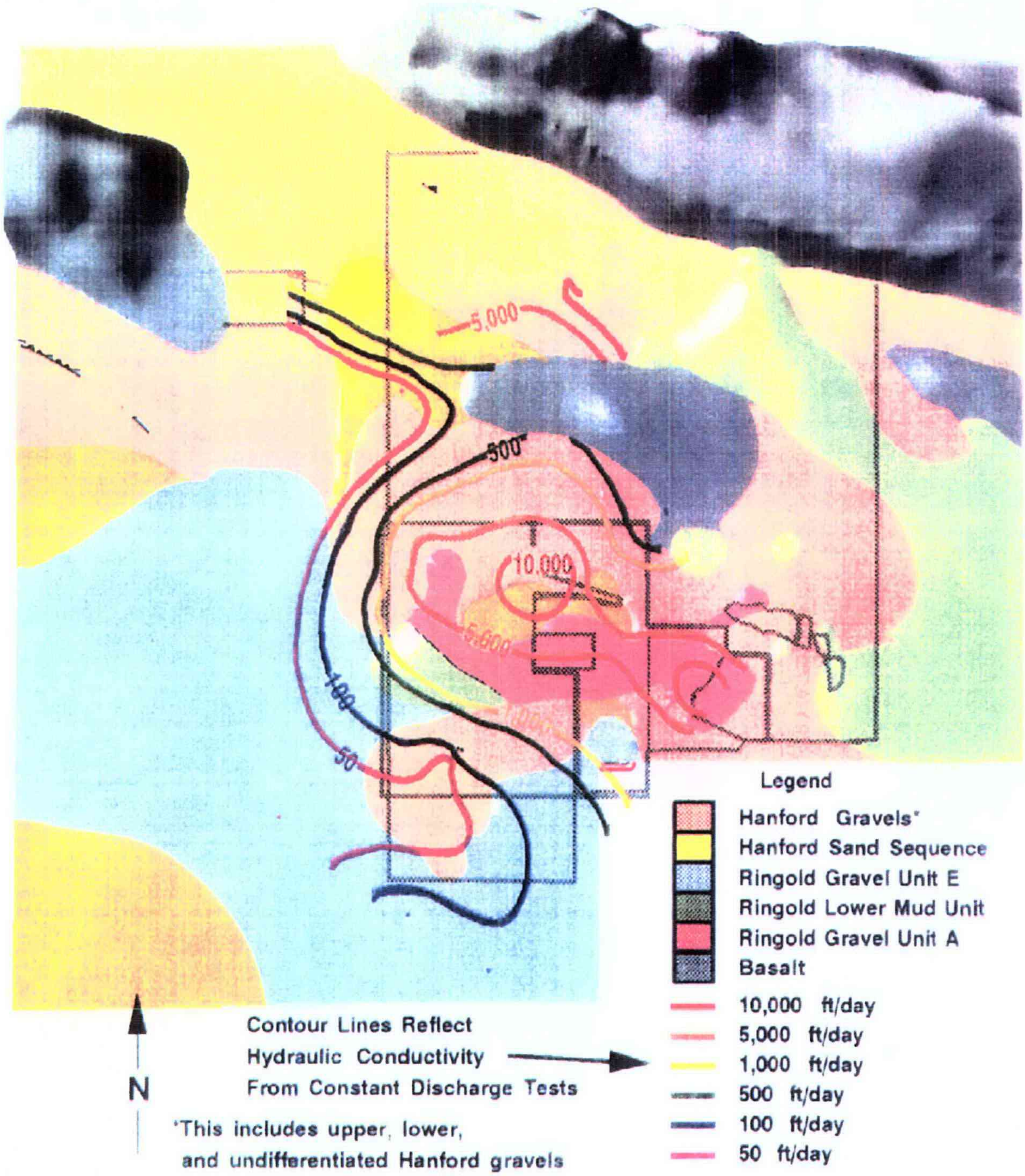


Figure 2-10. Isopach Map of the Hanford Formation Lower Gravel Sequence.

From DOE/RL-92-19, *200 East Groundwater Aggregate Area Management Study Report.*

FM = formation.

Figure 3-3. 1992 Geology at the Water Table with Hydraulic Conductivity Contours of the Uppermost Aquifer System.



From DOE/RL-92-19, *200 East Groundwater Aggregate Area Management Study Report.*

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Figure 3-4. December 1991 Water Table Elevation.

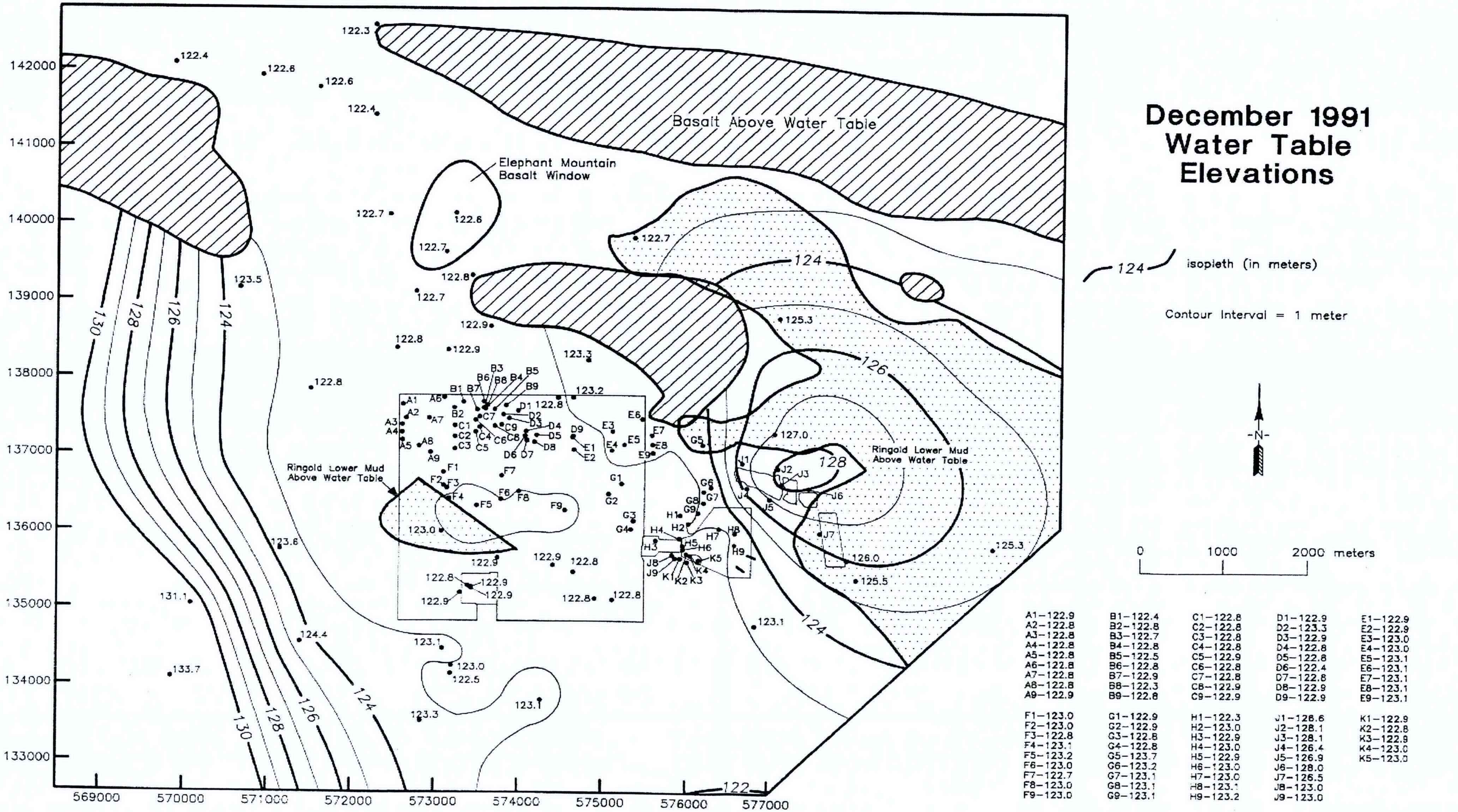
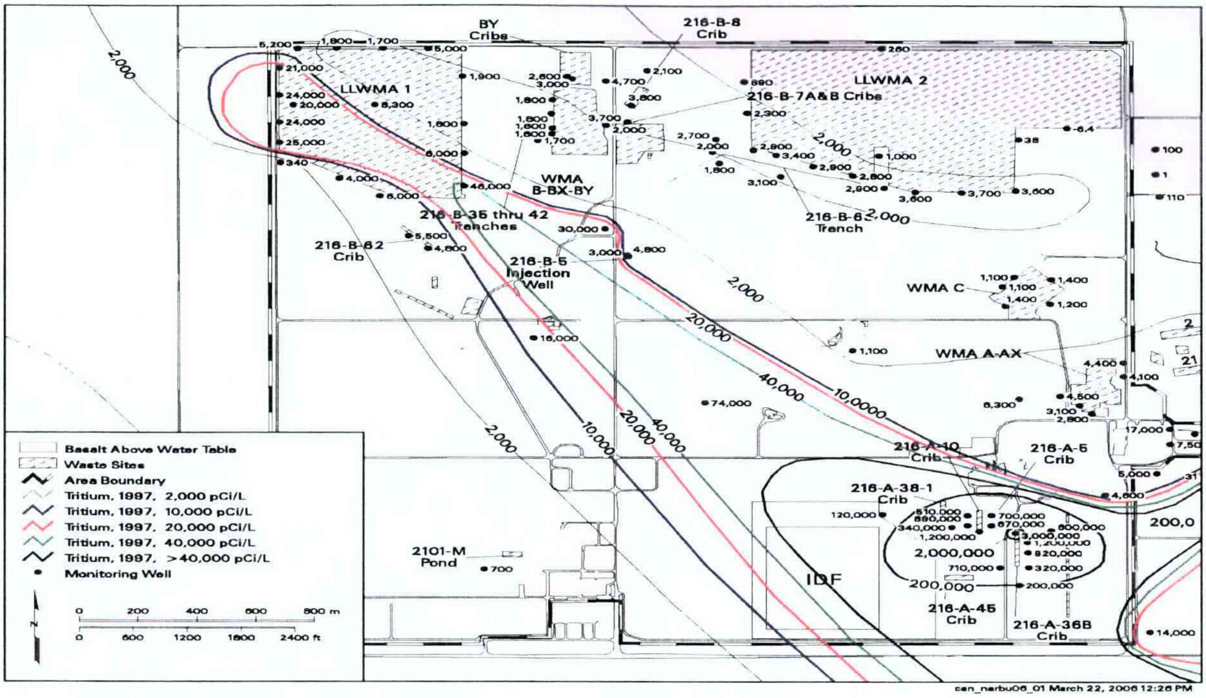


Figure 3-9. December 1991 Water Table Elevations.

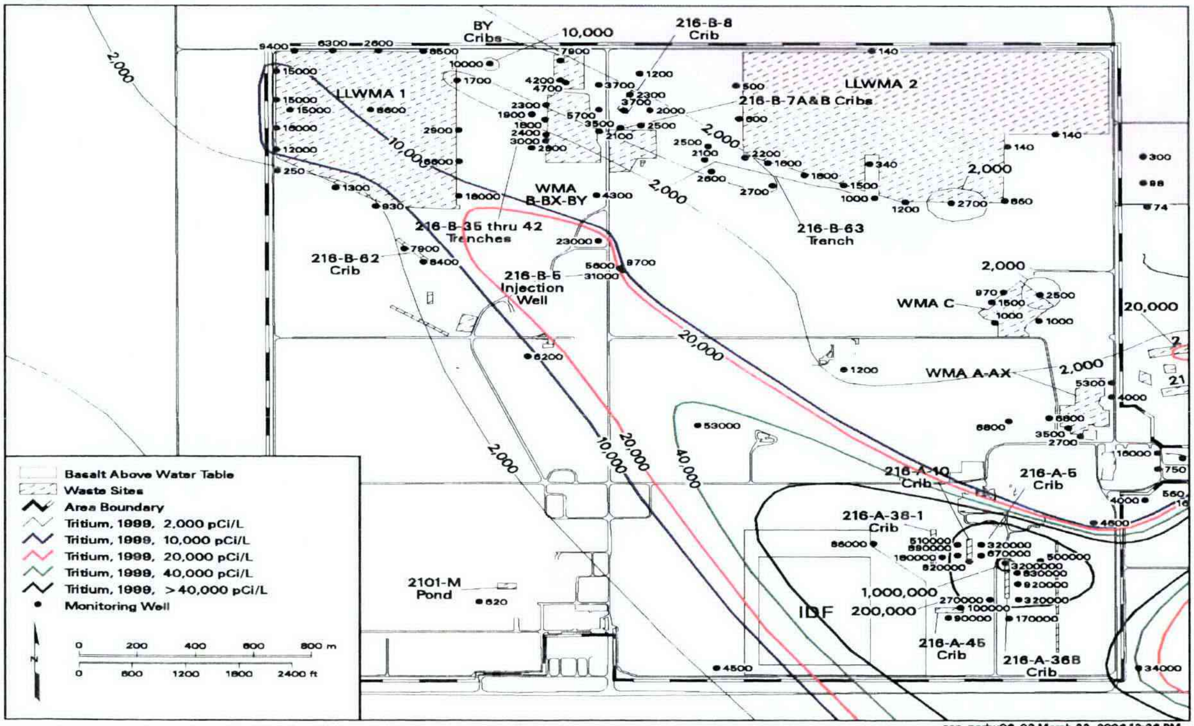
From DOE/RL-92-19, *200 East Groundwater Aggregate Area Management Study Report.*

Figure 3-5. Tritium Contour Map, 1997.



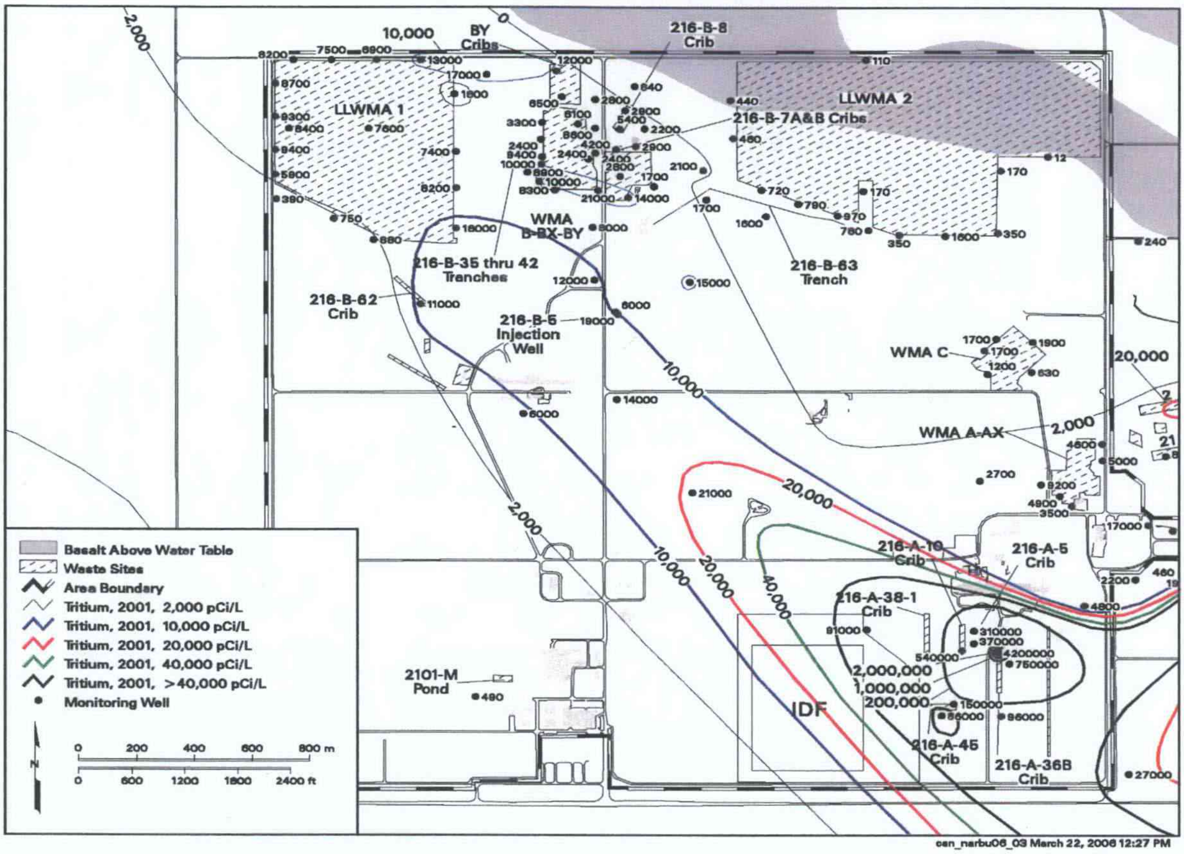
PNNL-11793, *Hanford Site Groundwater Monitoring for Fiscal Year 1997.*

Figure 3-6. Tritium Contour Map, 1999.



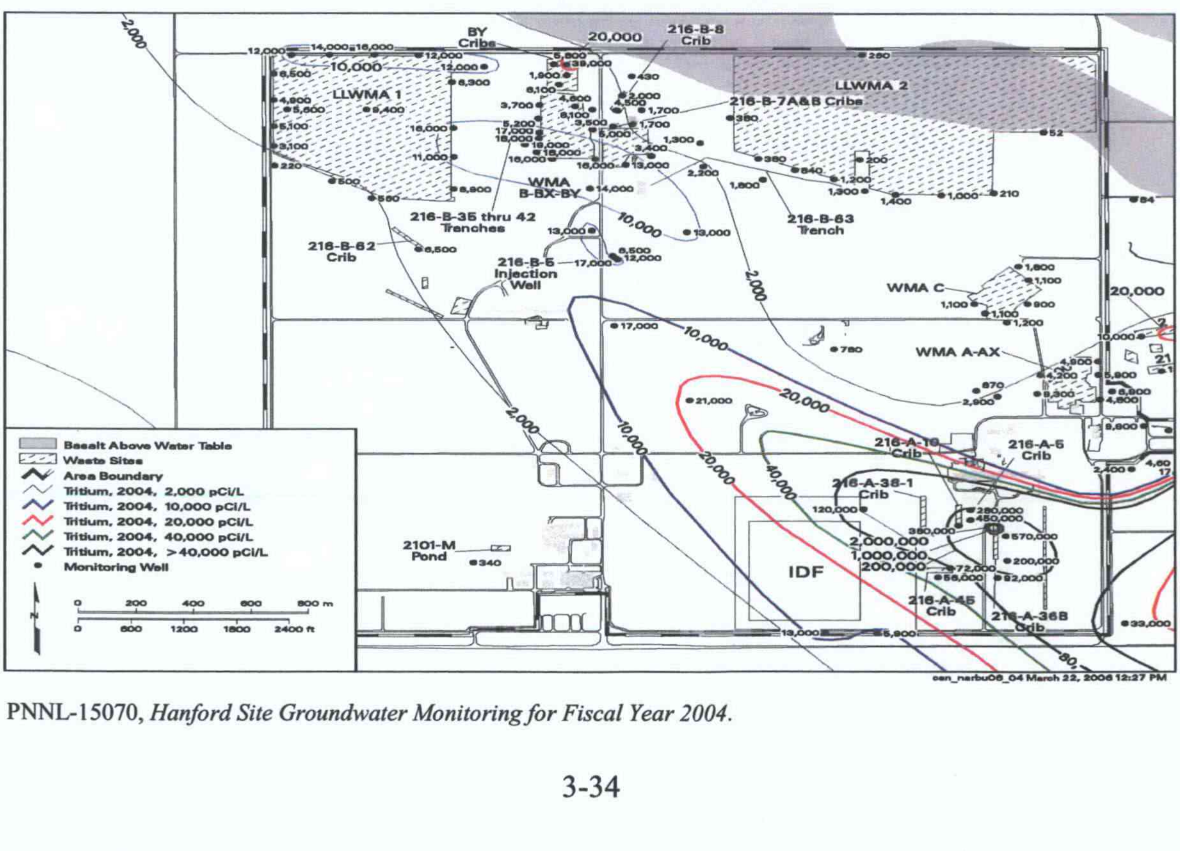
PNNL-13116, *Hanford Site Groundwater Monitoring for Fiscal Year 1999.*

Figure 3-7. Tritium Contour Map, 2001.



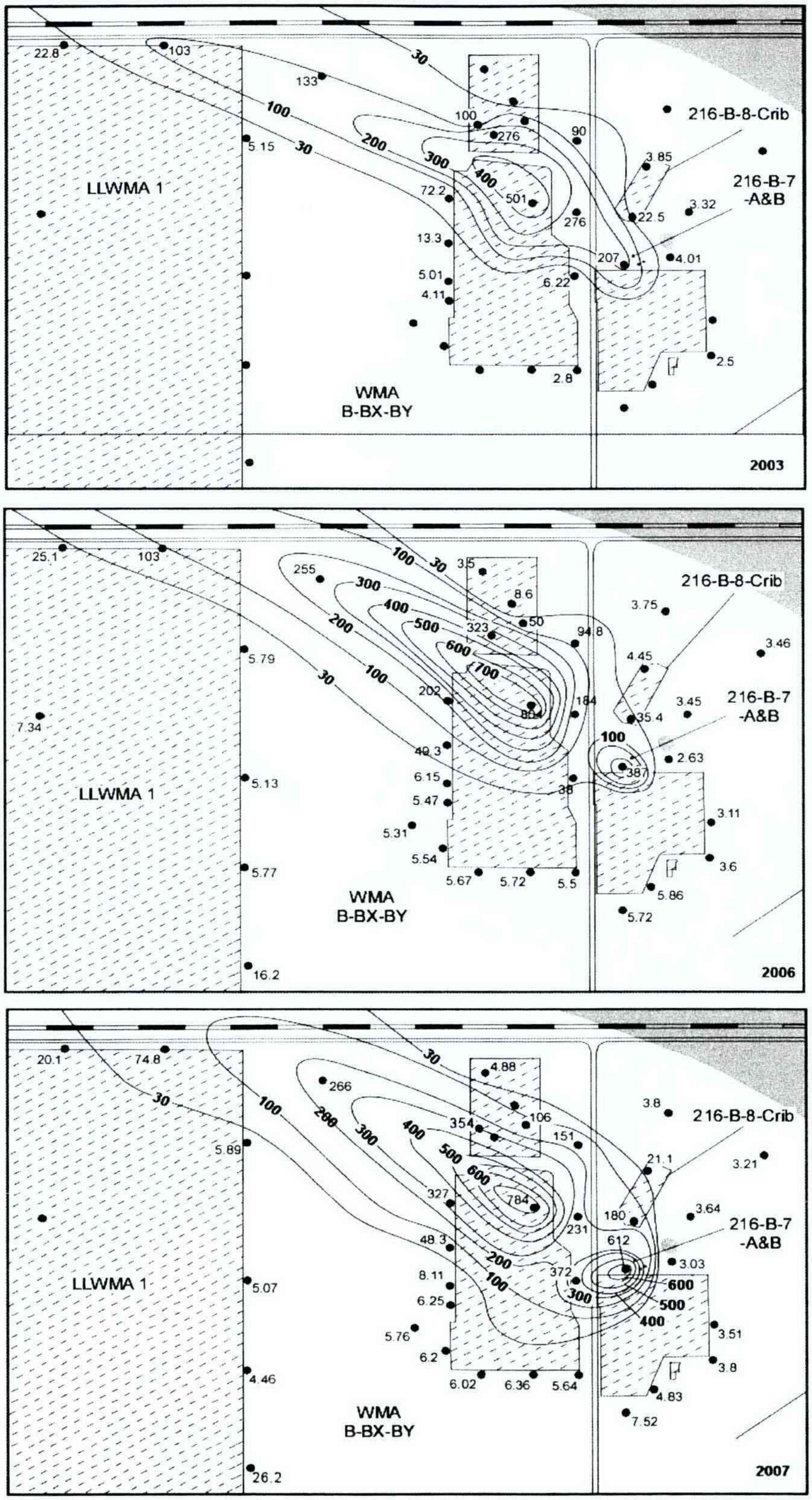
PNNL-13788, *Hanford Site Groundwater Monitoring for Fiscal Year 2001*.

Figure 3-8. Tritium Contour Map, 2004.



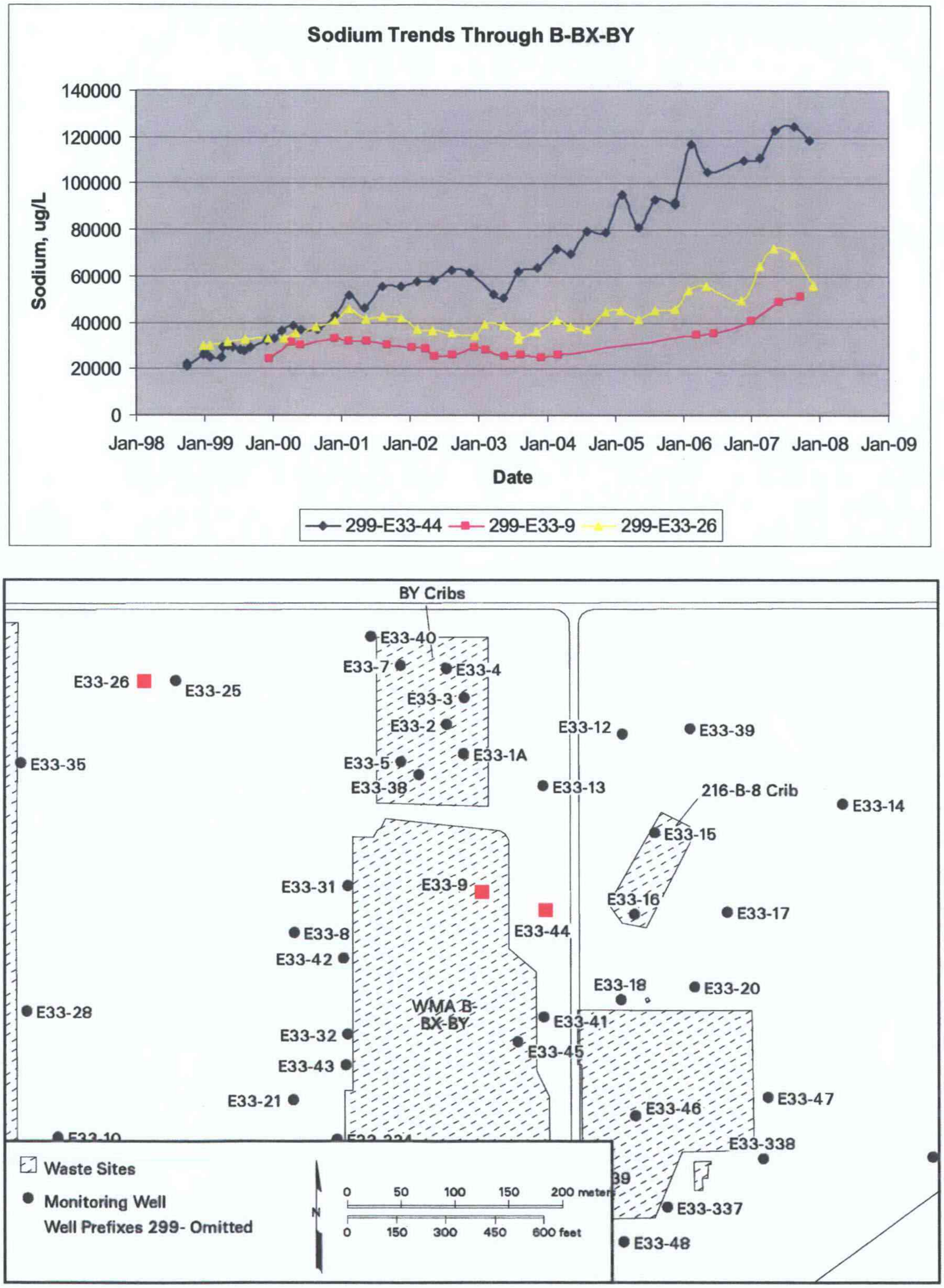
PNNL-15070, *Hanford Site Groundwater Monitoring for Fiscal Year 2004*.

Figure 3-9. Uranium Time Series for Waste Management Area B/BX/BY.



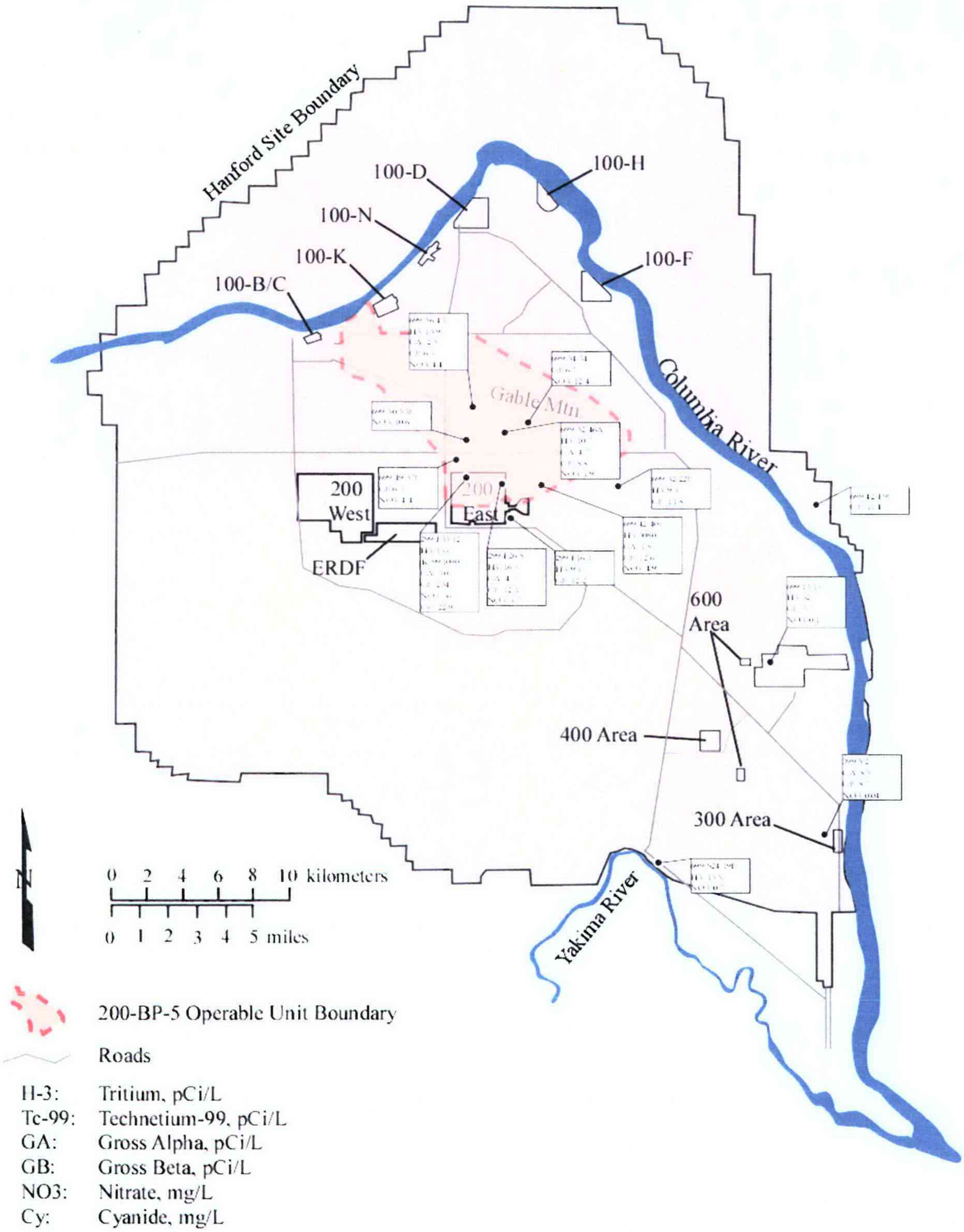
LLWMA = low-level waste management area.
WMA = waste management area.

Figure 3-10. Sodium Trend Results Through Waste Management Area B/BX/BY.



WMA = waste management area.

Figure 3-11. Distribution of Chemical and Radiological Constituents in the Rattlesnake Ridge Interbed Confined Aquifer, Fiscal Years 2003 Through 2005.



From PNNL-15670, *Hanford Site Groundwater Monitoring for Fiscal Year 2005.*
ERDF = Environmental Restoration Disposal Facility.

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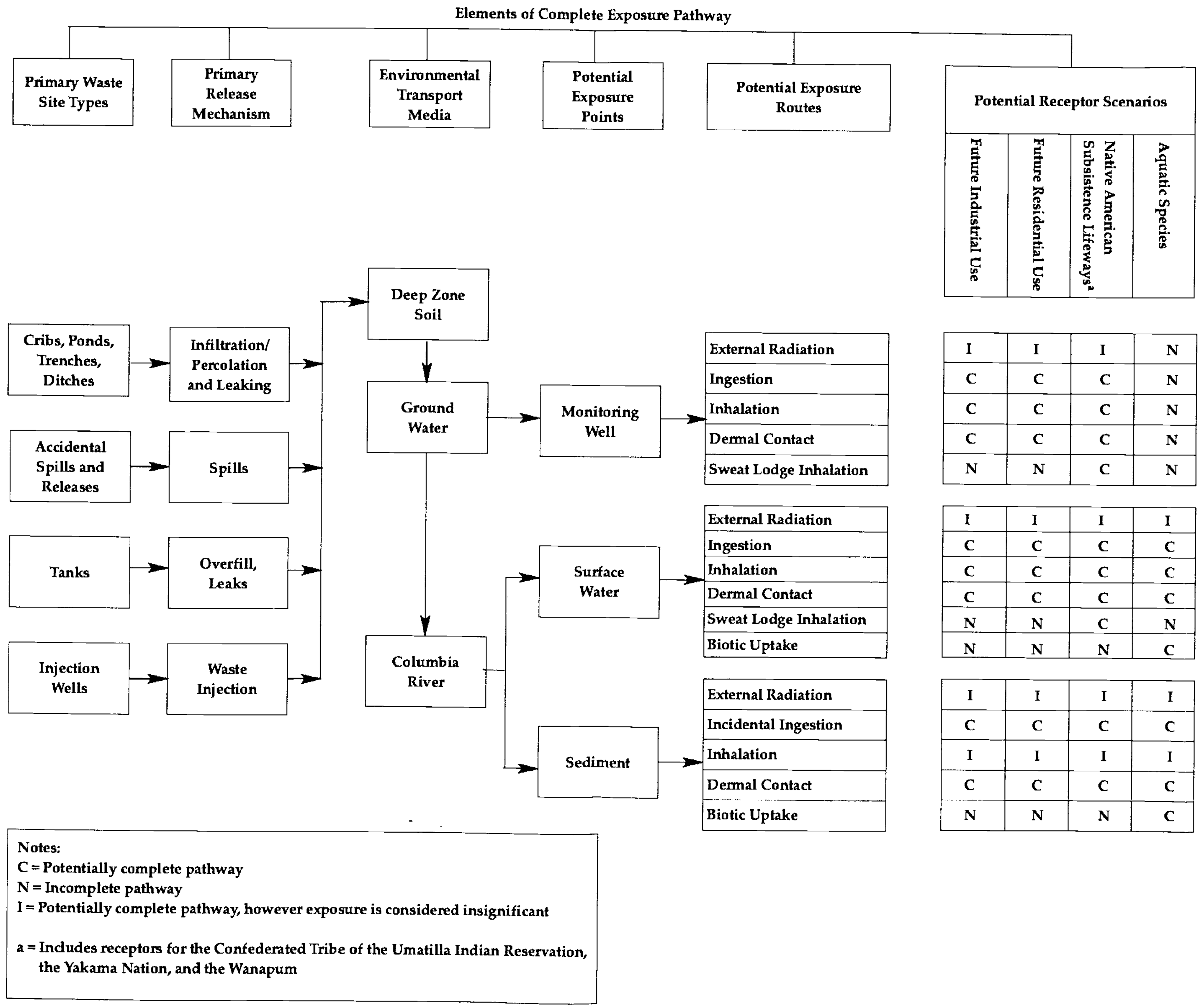
Figure 3-12. Conceptual Exposure Model for Potential Human Health and Ecologic Receptors for the 200-BP-5 Operable Unit.



Monitoring Well	Future Industrial Use	Future Residential Use	Native American Subsistence Lifeways[a]	Aquatic Species
External Radiation	I	I	I	N
Ingestion	C	C	C	N
Inhalation	C	C	C	N
Dermal Contact	C	C	C	N
Sweat Lodge Inhalation	N	N	C	N

Surface Water	Future Industrial Use	Future Residential Use	Native American Subsistence Lifeways[a]	Aquatic Species
External Radiation	I	I	I	I
Ingestion	C	C	C	C
Inhalation	C	C	C	C
Dermal Contact	C	C	C	C
Sweat Lodge Inhalation	N	N	C	N
Biotic Uptake	N	N	N	C

Sediment	Future Industrial Use	Future Residential Use	Native American Subsistence Lifeways[a]	Aquatic Species
External Radiation	I	I	I	I
Incidental Ingestion	C	C	C	C
Inhalation	I	I	I	I
Dermal Contact	C	C	C	C
Biotic Uptake	N	N	N	C

Table 3-1. 200-BP-5 Groundwater Contaminants Exceeding Drinking Water Standards.

Radionuclide			
Cs-137 [a]	Pu-239[a]	Sr-90 [a]	H-3 (tritium) [b, c]
I-129	Pu-240[a]	Tc-99 [b, d]	
Metal			
Uranium (total) [b]			
Non-Metal			
Cyanide [b, d]	Nitrate	Sulfate[b, c]	

[a]216-B-5 Reverse Well only.
[b]Waste Management Area B/BX/BY.
[c]218-E-10 and 218-E-12 Burial Grounds.
[d]Waste Management Area C.

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4.0 WORK PLAN RATIONALE

This chapter provides the rationale for performing the activities undertaken in performance of the RI/FS. The overall objectives of the RI are as follows.

- Refine the CSM describing the groundwater contamination sources, the nature and extent of groundwater contamination, and potential exposure scenarios.
- Provide data needed to support the future baseline risk assessment, which will be provided in the RI report.
- Provide information sufficient to support an evaluation of remedial alternatives as part of the FS.

Following EPA guidance, the rationale describes data needs identified and refined through application of the DQO process, and an approach to conducting the activities necessary to satisfy the data needs.

4.1 DATA NEEDS

Data needs for the 200-BP-5 Groundwater OU were developed in accordance with EPA/240/B-06/001. The DQO process is a seven-step planning approach used to develop a data-collection strategy consistent with data uses and needs. The goals of the process are to ensure that RI/FS data needs are adequately identified, representative, and of sufficient quality to support project objectives and decisions.

The DQO process was conducted in 2006 by a team of environmental professionals familiar with the Hanford Site and stakeholder interests. The DQO team members provided input on regulatory issues, waste-site status, contaminant plumes, and hydrogeology. Key decision makers from DOE, EPA, Ecology, and Tribal representatives participated in the process and provided input to the development of the characterization approach.

The initial evaluation of the 200-BP-5 Groundwater OU CSM and its major elements is presented in Section 3.1. Section 3.2 provides an overview of the 200-BP-5 Groundwater OU information known to date. An extensive quantity of information has been collected for much of the 200-BP-5 Groundwater OU. A network of wells provides data for a variety of purposes including monitoring of RCRA TSD units, past operations of liquid waste disposal sites, assessment of Site-wide conditions, and prior CERCLA investigations and interim actions. It also is recognized that this information was collected for a variety of purposes and that additional data are needed to address significant gaps in the CSM.

The data needs corresponding to each of the CSM elements is presented in Section 3.3. Table 4-1 summarizes the data needs identified in the DQO and in Section 3.3. The table relates the corresponding tasks and activities that are necessary to collect needed data. These tasks and activities are the basis for the RI activities summarized in Chapter 5.0.

4.2 WORK PLAN APPROACH

The work plan approach discussed describes the project assumptions and relates data-collection activities necessary for satisfying the identified data needs.

4.2.1 Project Assumptions

In formulation of this work plan, a number of assumptions were developed through the course of the DQO process and project planning. The project assumptions listed below provide a context to the conditions, expectations, and constraints by which the project is planned and implemented. These project assumptions are grouped by applicable topic.

- General project assumptions
  - The boundary of the 200-BP-5 Groundwater OU consists of the current aquifer, but not the vadose zone or perched water zones. Boundary definitions are intended to define spatial and geographic features of the OU and do not represent points of compliance with respect to contaminant plume risk assessment or evaluation of remediation alternatives.
  - Information obtained from activities in adjacent groundwater OUs will be included as available and efforts to obtain that data will not be duplicated.
  - Data generated during the 200-BP-5 Groundwater OU will be fully integrated with data and decision making (e.g., risk assessments) with River Corridor Groundwater OUs, as well as source OUs and RCRA TSD units.
  - Groundwater data resulting from sampling and analysis at all RCRA, RCRA past-practice, CERCLA, and Site-wide (AEA) monitoring wells will be used to support characterization of the 200-BP-5 Groundwater OU. These ongoing monitoring activities may be modified to accommodate collection of additional data as needed.
- Assumptions related to contamination sources
  - Vadose zone information obtained from ongoing monitoring and characterization activities for overlying RCRA TSD units and CERCLA source OUs will be integrated with the 200-BP-5 Groundwater OU RI, as they are made available. The main purpose for collecting vadose zone data and information is to provide input to modeling and risk assessment activities in support of the baseline risk assessment and the RI.
  - Source OU characterization data will be used to evaluate potential future impact to groundwater.
  - All potential sources of groundwater contamination remaining in the vadose zone (e.g., WMA tank farms, trenches, burial grounds, and cribs) will be considered in the RI/FS process. It is assumed that responsibility for vadose zone characterization (which includes evaluation of potential for impact to groundwater) and remediation remains with the individual waste-site OU project and that there will be an integrated effort to meet data needs. This includes the current supplemental vadose zone investigation effort.

- Assumptions related to contaminant movement and pathways
  - Vadose zone and groundwater plume characterization will be three-dimensional in target areas of concern (i.e., include vertical distribution of contaminants).
  - Characterization will be driven by one or more conceptual model parameters (e.g., changing flow directions, density-driven flow, declining water table elevations, and chemical complexing) to allow planning for field investigations.
  - Continued development of transport parameters and corroboration of modeled results may be necessary to improve upon past groundwater contaminant modeling efforts. A new Site-wide contaminant transport model will be ready to support modeling exercises for the RI.
  - Common points of calculation will be established (e.g., waste-site boundaries, TSD unit boundaries, Core Zone boundary, mutually agreed to intermediate boundaries, and the river). These points of calculation are for purposes of analysis, and are not to be construed as points of compliance, which have a regulatory basis. Note that modeling and remediation of the vadose zone remains with the individual waste-site OU project and that there will be an integrated effort to meet data needs mentioned above.
  - Modeling will include prediction of contaminant concentration at various points of calculation including waste-site boundaries, TSD unit boundaries, Core Zone boundary, mutually agreed to intermediate boundaries, and the river.
  - Modeling will include impacts on groundwater from vadose zone sources (assumed inventory and uncertainty, and likely response scenarios). Note that modeling from the source waste site through the vadose zone remains with the individual waste-site OU project, however, obtaining the data needs will be an integrated effort.
  - Uncertainties in characterization data, modeling results, and risk calculation will be identified and described as applicable.
- Assumptions regarding exposure scenarios and receptors
  - The baseline risk assessment will evaluate the groundwater for its maximum beneficial use.
  - Exposure scenarios relevant to groundwater within the 200-BP-5 Groundwater OU will be developed before the baseline risk assessment.
- Assumptions influencing the scope of the FS
  - Waste left in place at source OUs will require long-term monitoring.
  - Remedies other than monitored natural attenuation (MNA) will be considered as appropriate.
  - Data obtained after initial implementation of the RI/FS process (e.g., UPRs and characterization of waste sites) will be incorporated as appropriate during the 5-year reviews.
- Schedule assumptions
  - Tri-Party Agreement milestones provide the timeframe in which RI/FS activities must be conducted.
  - Sufficient data from groundwater, tank farms, and other waste sites will be available to develop a proposed plan for the 200-BP-5 Groundwater OU by January 2009. The

record of decision may be geographic in scope, action-specific, or a combination of both.

4.2.2 Data-Collection Activities

The 200-BP-5 Groundwater OU is a geographically large area with numerous groundwater contamination sources and multiple, often overlapping, groundwater contaminant plumes that exceed primary DWSs. Planning for RI/FS work activities will be organized with respect to the known groundwater contaminant plumes.

Table 4-1 summarizes the data needs identified in Section 3.3 and links them to the characterization-related tasks and associated data-collection activities. Chapter 5.0 describes the activities to be undertaken during the RI, including field sampling, data evaluation, risk evaluation, and reporting. The results of the RI and the updated CSM will be documented in a future RI report. This information will provide the basis for the baseline risk assessment for RI characterization and preparation of the RI/FS report. The SAP (Appendix A) describes specific sampling activities and analytical requirements necessary to satisfy the project DQOs.

Table 4-1. Summary of 200-BP-5 Groundwater Operable Unit Data Needs and Associated Remedial Investigation/Feasibility Study Activities. (4 Pages)

Data Needs	Activities
Contaminant Sources	
Vadose zone and groundwater data are needed in the vicinity of tank 241-BX-102 and the BY Crib complex to help identify nature and extent of deep vadose zone contamination and groundwater contamination in the area. The precise locations are subject to adjustment based on results of HRR. • North side of BY Cribs • South side of BY Cribs • North side of BX Tank Farm (WMA-B/BX/BY Tank Farm) north of tank 241-BX-103 and south of tank 241-BY-101	• Complete HRR measurements and evaluate resistivity model to discern presence and potential geometry of contaminants. • Drill borings to collect vadose zone sediment samples and aquifer sediments and analyze for chemical, radiological, and physical parameters. • Install new monitoring wells and sample local monitoring wells for analysis of chemical and radiological parameters. • Model vadose zone contaminant transport to predict future concentrations of contaminants in groundwater.
Vadose zone and groundwater data are needed in the vicinity of the 216-B-6 Reverse Well.	• Drill boring to collect vadose zone sediment samples and aquifer sediments and analyze for chemical, radiological, and physical parameters. • Install a new monitoring well and sample local monitoring wells for analysis of chemical and radiological parameters. • Model vadose zone contaminant transport to predict future concentrations of contaminants in groundwater.
Additional data are necessary in the vicinity of the WMA-C Tank Farm to determine the extent of nitrate and Tc-99 in the groundwater and to refine the groundwater flow direction.	• Drill borings to collect aquifer sediments and analyze for chemical, radiological, and physical parameters. • Install new monitoring wells and sample local monitoring wells for analysis of chemical and radiological parameters. • Model vadose zone contaminant transport to predict future concentrations of contaminants in groundwater. • Collect depth-discrete groundwater samples and analyze for nitrate, Tc-99, and other geochemical constituents.

Table 4-1. Summary of 200-BP-5 Groundwater Operable Unit Data Needs and Associated Remedial Investigation/Feasibility Study Activities. (4 Pages)

Data Needs	Activities
Vadose zone data are needed to further investigate source (i.e., possibly the 216-B-7A Crib) of significant uranium concentrations measured during a recent geophysical at well 299-E33-18. In addition, hydraulic properties are required for evaluation of remedial alternatives. • West of 216-7A Crib	• Complete HRR measurements and evaluate resistivity model to discern presence and potential geometry of contaminants. • Drill borings to collect vadose zone sediment samples and aquifer sediments and analyze for chemical, radiological, and physical parameters. Evaluate uranium isotopic ratio data to determine likely source of contaminants. • Install new monitoring wells and sample local monitoring wells for analysis of chemical and radiological parameters. • Model vadose zone contaminant transport to predict future concentrations of contaminants in groundwater. • Complete aquifer tests to evaluate aquifer properties.
Conservative fate and transport modeling for the 216-B-12 Crib indicated that nitrate/nitrite, nitrate, and total uranium within the soils will contribute to unacceptable groundwater contamination. Additional investigation of this vadose zone contamination is necessary to predict potential future impacts to groundwater.	• Drill boring to collect vadose zone sediment samples and aquifer sediments and analyze for chemical, radiological, and physical parameters. • Install a new monitoring well and sample local monitoring wells for analysis of chemical and radiological parameters. • Model vadose zone contaminant transport to predict future concentrations of contaminants in groundwater.
Additional COC analyses of deep vadose zone soils in the vicinity of the 216-C-1 Crib is necessary to understand potential future groundwater impacts from probable vadose zone contamination (particularly chromium, uranium, plutonium, and strontium).	• Drill borings to collect vadose zone sediment samples and aquifer sediments and analyze for chemical, radiological, and physical parameters. • Install new monitoring wells and sample local monitoring wells for analysis of chemical and radiological parameters. • Model vadose zone contaminant transport to predict future concentrations of contaminants in groundwater.
Vadose Zone Pathways	
The depth and possible lateral extent of significant low-permeability layers in the Hanford formation in the vicinity of WMA-B/BX/BY Tank Farm and BY Cribs is not known and likely affects the movement of contaminants.	• Investigate and sample physical and chemical characteristics of low-permeability layers using soil borings. • Spectral-gamma logs and neutron moisture logs can help locating low-permeability intervals and other strata, which may affect contaminant migration in the vadose zone. Variations in natural radionuclide (K-40, Th-232, and U-238) concentrations are known to be useful stratigraphic indicators. • Create three-dimensional graphics of low-permeability soil layers to predict pathways in vadose zone.

Table 4-1. Summary of 200-BP-5 Groundwater Operable Unit Data Needs and Associated Remedial Investigation/Feasibility Study Activities. (4 Pages)

Data Needs	Activities
Identify soil characteristics of strata in the vadose zone to aid in modeling potential future movement of contaminants. • WMA-B/BX/BY Tank Farm and BY Cribs • 216-B-12 Crib • 216-C-1 Crib • 216-B-6 Crib	• Investigate and sample physical and chemical characteristics of key strata using soil borings. • Create three-dimensional graphics of strata in vicinity of WMA-B/BX/BY Tank Farm and BY Cribs to predict pathways in vadose zone. Three-dimensional graphics will not be generated for the 216-B-12 and 216-C-1 Cribs due to limited investigation.
Groundwater flow directions for the unconfined aquifer in sub-areas #3 and #4 are not defined.	• Document recent historical efforts to determine groundwater flow directions (completed as part of DQO process). • Measure groundwater flow direction in select wells in areas of the OU needing further definition.
Potential migration of contaminants from the unconfined aquifer to the Rattlesnake Ridge interbed confined aquifer is not well defined. • Well 299-E33-12 east of BY Cribs	• Investigate sediments and groundwater upgradient of well 299-E33-12 to determine the extent and cause of groundwater contamination. • Compare monitoring data from new well(s) with data from well 299-E33-12. • Decommission well 299-E33-12, if necessary.
Groundwater Contaminant Plumes	
Define extent and geometry of major groundwater contaminants. • Vicinity of sub-areas #3, #4, #5, and #6	• Install new monitoring wells and sample local monitoring wells for analysis of COPCs and COCs.
Identifying potential migration of contaminants from the overlying unconfined aquifer in the vicinity of old wells (e.g., 299-E33-12, located in sub-area #4) or eroded windows through the uppermost basalt aquitard (e.g., near wells 699-53-55B and 699-53-55C in sub-area #3).	• Install new monitoring wells to the north and south of well 299-E33-12 to determine the extent of contamination within the upper confined aquifer. • Decommission well 299-E33-12. • Install new monitoring wells within the unconfined aquifer and upper confined aquifer south of the 699-53-55 series wells. • Add all new wells to the monitoring network.
Define vertical variations in contaminant concentrations within the unconfined aquifer.	• Collect depth-discrete samples from new and existing groundwater wells.
Receptors	
Identification of exposure scenarios for the groundwater within the 200-BP-5 Groundwater OU is necessary to allow risk evaluation during the baseline risk assessment.	• Develop exposure scenarios before end of RI.

Table 4-1. Summary of 200-BP-5 Groundwater Operable Unit Data Needs and Associated Remedial Investigation/Feasibility Study Activities. (4 Pages)

Data Needs	Activities

COC = contaminant of concern.
COPC = contaminant of potential concern.
DQO = data quality objective.
HRR = high-resolution resistivity.
OU = operable unit.
RI = remedial investigation.
WMA = waste management area.

5.0 REMEDIAL INVESTIGATION/FEASIBILITY STUDY TASKS

5.1 PROJECT ORGANIZATION

The 200-BP-5 Groundwater OU RI/FS project is coordinated and managed under the support of DOE's Groundwater Remediation Project. The lead for managing the total effort is assigned to the Waste Disposal/Groundwater Remediation Project contractor, which is FH. The contractor has the overall responsibility to ensure the work planned and undertaken is performed in a consistent and effective manner that protects human health and the environment. The 200-BP-5 Groundwater OU RI/FS project organization is described below, and the organizational structure is depicted in Figure 5-1.

- Project manager: The project manager provides oversight for all activities and coordinates with RL and the regulators in support of RI/FS activities. In addition, support is provided to the task lead to ensure that work is performed safely and cost effectively.

- Task lead: The task lead is responsible for direct management of sampling documents and requirements, field activities, and subcontracted tasks. The task lead ensures that the field team lead, samplers, and others responsible for implementation of the field sampling activities are provided with current copies of the SAP. The task lead works closely with QA, Health and Safety, and the field team lead to integrate these and the other lead disciplines in planning and implementing the RI/FS workscope. The task lead also coordinates with, and reports to, RL, the regulators, and the Hanford Management Contractor on all sampling activities.

- Quality Assurance engineer: The QA engineer coordinates with the task lead and is responsible for QA issues on the project. Responsibilities include overseeing implementation of the project QA requirements; reviewing project documents (including SAPs and the QAPjP); and participating in QA assessments on sample collection and analysis activities, as appropriate.

- Waste Management lead: The Waste Management lead communicates policies and procedures and ensures project compliance for safe and cost-effective storage, transportation, disposal, and tracking of investigation-derived waste. Other responsibilities include identifying waste management sampling and characterization requirements to ensure regulatory compliance with WAC 173-303, "Dangerous Waste Regulations," and the applicable waste control plan.

- Field team lead: The field team lead has overall responsibility for the planning, coordinating, and execution of field characterization activities. Specific responsibilities include converting the sampling design requirements into field task instructions that provide specific direction for field activities. Responsibilities also include directing training, mock-ups, and practice sessions with field personnel to ensure that the sampling design is understood and can be performed as specified. The field team lead communicates with the task lead to identify field constraints that could affect the sampling design. In addition, the field team lead directs the procurement and installation of materials and equipment needed to support the fieldwork.

The field team lead oversees field-sampling activities, including sample collection, packaging, provision of certified clean sampling bottles/containers, documentation of sampling activities in controlled logbooks, chain-of-custody documentation, and packaging and transportation of samples to the laboratory or shipping center.

The field team lead, samplers, and others responsible for implementation of field sampling activities will be provided with current copies of the SAP and QAPjP.

- Radiological Engineering lead: The Radiological Engineering lead is responsible for radiological engineering and health physics support within the project. Specific responsibilities include conducting as-low-as-reasonably-achievable reviews, exposure and release modeling, and radiological control optimizing for all planned work. In addition, radiological hazards are identified and appropriate controls are implemented to minimize worker exposure to radiological hazards. The Radiological Engineering lead interfaces with the project Health and Safety representative and plans and directs radiological control technician support for all activities.

- Sample and Data Management organization: The Sample and Data Management organization selects the laboratories that perform the soil and groundwater analyses. This organization also ensures that laboratories conform to Hanford Site internal laboratory QA requirements, or their equivalent, as approved by RL, EPA, and Ecology. The Sample and Data Management organization initiates audits of the laboratories periodically to ensure compliance. Sample and Data Management receives analytical data from the laboratories, enters the data into HEIS, and arranges for data validation. Validation will be performed on completed data packages (including quality control samples) by FH's Environmental Information Services group or by a qualified independent contractor.

- Health and Safety organization: The responsibilities of the Health and Safety organization include coordinating industrial safety and health support within the project, as carried out through safety and health plans, job hazard analyses, and other pertinent safety documents required by Federal regulation or by internal FH work requirements. In addition, Health and Safety provides assistance to project personnel in complying with applicable health and safety standards and requirements. Personnel protective clothing requirements are coordinated with Radiological Engineering.

5.2 REMEDIAL INVESTIGATION CHARACTERIZATION ACTIVITIES

This section provides an overview of the planned RI characterization activities. These activities are designed to obtain data and information to support resolution of data gaps identified in Chapter 3.0. The characterization activities are categorized into the following major tasks:

- Drilling and construction of new wells
- Vadose zone sampling
- Groundwater sampling
- Geophysical investigations (surface and borehole methods)
- Hydrologic testing
- Groundwater monitoring of existing and new wells.

Sample collection methods, depths and frequency, and performance requirements are described in detail in the SAP (Appendix A).

5.2.1 Drilling and Construction of New Wells

Fifteen new wells will be installed to support the 200-BP-5 Groundwater OU RI. Of these wells, six are primarily for vadose zone characterization, three are for the confined aquifer, and six are for the unconfined aquifer. Data-collection results from the planned wells will provide the information necessary to determine if the contingency wells will be installed. The proposed locations of the planned wells are shown on the respective focus area maps, as indicated in Table 5-1. Maps showing locations of RI activities are presented in sub-area #3 (Figure 5-2), sub-area #4 (Figure 5-3), sub-area #5 (Figure 5-4), sub-area #6 (Figure 5-5), and sub-area #7 (Figure 5-6).

Well locations were determined during the DQO process and represent locations where additional vadose zone or groundwater data are needed in the OU. The primary rationale for each well location is summarized in Table 5-2. Additional information describing the basis for well location selection is provided in WMP-28945.

The primary location rationale listed in Table 5-2 generally represents localized data needs within the OU. The following list summarizes universal data objectives that apply to all of the proposed wells to be drilled during the RI.

- Describe the stratigraphy of suprabasalt sediments and identify contact depths for significant changes in lithology and key stratigraphic units.

- Identify depths and thicknesses of low-permeability strata and other features that might influence vertical and lateral spreading of vadose zone contamination.

- Identify depth to top of basalt.

- Collect samples from key strata to evaluate physical and geochemical properties to improve reliability of modeling in support of baseline risk assessment and remedial design.
- Monitor water levels in completed wells to aid determination of flow direction and an estimation of groundwater velocity.

Drilling and well construction will be performed in compliance with requirements defined in WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells." At selected locations, groundwater well designs will allow for dual-purpose uses (e.g., groundwater monitoring and pump-and-treat remediation). DOE/RL-2006-55 details the well design and sampling requirements for proposed wells "F," "I," and "J." Well design and sampling requirements for proposed wells "A," "B," "C," "D," "E," "G," "H," "K," "L," "M," and "N" are summarized in the SAP (Appendix A). The schedule for drilling and well installation is detailed in Chapter 6.0.

5.2.2 Sediment Sampling

Sediment samples will be collected during the drilling activities to obtain information and data on physical soil properties and geochemical parameters, as well as to assess the nature and extent of subsurface contamination. WMP-28945 identified sediment sampling needs in the vadose zone and aquifers (referred to as saturated sediments). These sampling needs are summarized in the subsections below.

5.2.2.1 Vadose Zone Sediment Sampling

Vadose zone sediment samples for targeted analytes will be collected from selected wells for two primary purposes: (1) to allow laboratory measurement of various geochemical and physical parameters to support future modeling, and (2) to analyze for the COPCs identified in WMP-28945. Vadose zone sampling requirements are specified in the SAPs. In general, samples will be collected using grab and split-spoon methods. Sample collection methods and analytical performance requirements are summarized in the associated SAPs. Table 5-3 summarizes the planned vadose zone sediment sampling activities to support the RI.

5.2.2.2 Saturated Sediment Sampling

Saturated sediment sampling requirements typically will begin at the historical high water table elevation, as identified in the SAPs. Saturated samples will be collected to support measurement of geochemical and physical modeling parameters and to assess the nature and extent of groundwater COPCs in the aquifer and formerly saturated sediments. In general, samples will be collected using grab and split-spoon methods. Sample collection methods and analytical performance requirements are summarized in the associated SAPs. Table 5-4 summarizes the planned saturated sediment sampling activities to support the RI.

5.2.3 Groundwater Sampling During Drilling

Groundwater samples will be collected from selected wells during the drilling operations. Groundwater samples collected during drilling will be collected to assess the lateral and possibly vertical distribution (where sufficient aquifer thickness occurs) of COPCs. Groundwater samples during drilling will be collected using a depth-discrete sampling device (e.g., KABIS[9] sampler) and grab methods (e.g., bailer or air-lift methods) or submersible pump for non-depth-discrete samples. Sample collection methods and analytical performance requirements are summarized in the associated SAPs. Table 5-5 summarizes the planned groundwater sampling activities to support the RI.

5.3 HYDROLOGIC TESTING

Four types of aquifer tests are identified for this data-collection effort: slug tests, tests during well development, single-well tracer tests, and constant discharge single- or multiple-well pumping tests. The test method employed is dependent on the observed geologic and hydrologic conditions, as well as the overall water quality at each borehole location. Each of these proposed aquifer test methods is described in Table 5-6.

5.3.1 Slug Tests

Slug tests are commonly used at the Hanford Site to provide initial estimates of hydraulic properties (e.g., range and spatial/vertical distribution of K_h) because of their ease of implementation and relatively short duration. Additionally, slug tests do not require management of discharge water as is required by pumping test methods. Because of the small displacement volumes employed during slug tests, the subsequent hydraulic property data are representative of conditions relatively close to the well.

Multi-stress slug tests will be performed in selected boreholes before well completion. These tests involve injecting (injection test) and removing (withdrawal test) a slugging rod of known displacement volume. If time allows, two different size slugging rods will be used to impart varying stress levels for individual slug tests. The slug tests are repeated at each stress level to assess reproducibility of the test results. Comparison of the normalized slug-test responses is useful for assessing the effectiveness of well development and the presence of near-well heterogeneities and dynamic skin effects, as noted in Butler, 1997, *The Design, Performance, and Analysis of Slug Tests*.

The slug-test data will be analyzed using the semi-empirical, straight-line analysis method described in Bouwer and Rice, 1976, "A Slug Test for Determining Hydraulic Conductivity of Unconfined Aquifers with Completely or Partially Penetrating Wells"; and Bouwer, 1989, "The Bouwer and Rice Slug Test – An Update"; and the type-curve-matching method for unconfined aquifers presented in Butler, 1997.

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[9] KABIS sampler is a product of Sibak Industries, San Marcos, California.

5.3.2 Well-Development Pumping Tests

To model groundwater flow through an aquifer, aquifer parameters (including K_h, aquifer thickness, and storage coefficient) are necessary. Analysis of data from single-well aquifer tests will generate an estimate of aquifer transmissivity. Because transmissivity is the product of K_h and aquifer thickness, such pumping tests can yield average values of K_h, if aquifer thickness is known.

All new wells at the Hanford Site are developed before being accepted for production (i.e., extraction or injection) or monitoring activities. Well development is the process of removing fine-grained particles close to the well screen. For production wells, development enhances well performance. For monitoring wells, the primary objective of development is to increase the hydraulic connection with the aquifer thus enabling collection of representative samples and improving well efficiency (maximum production at a minimum drawdown). Well development generally is concluded once the turbidity of the pumped water is measured at or below 5 nephelometric turbidity units. The secondary objective of well development is to collect water-level response data at the pumping well using a pressure transducer and data-logger. These tests, when they are conducted by pumping at a constant discharge rate, can be considered short-term aquifer-pumping tests. This is most useful with wells screened across the confined aquifers. Unconfined aquifers have a more complex "gravity response" to pumping, which generally means that for an accurate estimate of transmissivity, the well must be pumped longer than for a confined aquifer.

The short-term well-development aquifer-pumping tests generally are conducted for 100 minutes or less, followed by at least a one-half hour recovery test. Water-level response is recorded by the data-logger. The geologist records discharge rate periodically either from a totalizing meter on the discharge pipe or using a bucket and stopwatch (typically both). The duration of the pumping test always is limited by the capacity of the purgewater truck, which receives the pumped water. Water is never disposed to the ground surface due to possible spread of contamination.

Data obtained during the short-term well-development aquifer-pumping tests typically is analyzed for transmissivity using straight-line methods on a semi-log graph. Log-log methods of analysis are available when conducting multiple well tests, using a pumping well and one or more observation wells. Multiple-well tests are preferred, although they are rarely employed during well development due to the distance between wells, limited discharge rates (i.e., limited drawdown), and short pumping duration.

Combining well-development pumping test data with other aquifer test methods will enhance the reliability of the aquifer test analysis.

5.3.3 Single-Well Tracer Tests

Single-well tracer tests, in conjunction with depth-discrete groundwater sampling and analysis, can add a third dimension to the essentially two-dimensional results obtained by conventional sampling and hydraulic testing. Three-dimensional data can substantially improve the accuracy of groundwater flow modeling and site-specific mass transport calculations.

Two single-well tests that have proven generally useful and have been applied at the Hanford Site are the point-dilution test and the drift-and-pumpback test. The two tests can be performed independently or combined in a single field experiment.

The point-dilution test yields a profile of K_h in a screened well when the concentration of a tracer such as bromide is measured as a function of both time and depth. Only a small volume of a tracer solution concentrate needs to be introduced to the well bore, and the test (conducted under natural gradient) requires no pumping. A submersible instrument for tracer measurement, test procedures, and typical results are described in Hall, 1993, "Single-Well Tracer Tests in Aquifer Characterization."

The drift-and-pumpback test originally was devised as a method for estimating flow rate independent of gradient measurement and stress tests. Like the point-dilution test, the drift-and-pumpback test is initiated by introducing a small volume of tracer to the well bore. The tracer then is allowed to migrate from the well under natural hydraulic gradient, usually for a few days or longer, depending on local conditions. Finally, the tracer slug is recovered by pumping, and the tracer concentration in the pumped effluent is monitored as a function of time (assuming constant discharge). Interpretation of the test is based on the amount of pumping required to recover the center of mass of the tracer slug.

Just as with conventional hydrogeologic analysis, the test interpretation requires an estimate of effective porosity. However, Hall et al., 1991, "A Method for Estimating Effective Porosity and Ground-Water Velocity," showed that conventional test results plus the results of a drift-and-pumpback test together yield a unique estimate of the local effective porosity and groundwater movement. Similarly, when point-dilution results are combined with the results of conventional methods, the tracer results can be recalibrated as a direct profile of aqueous mass transport.

The point-dilution calibration is valid for other wells of substantially similar construction, so the test could be used to investigate flow in those areas of the 200-BP-5 Groundwater OU where gradients are shallow and therefore ambiguous. A three-dimensional map of the rate of aqueous mass transport would be a significant benefit for locating pathways.

5.3.4 Single- or Multiple-Well Pumping Tests

Single- or multiple-well pumping tests are preferred aquifer test methods for determining aquifer characteristics at a greater distance from the well bore. Aquifer properties such as transmissivity, storativity, and boundary conditions can be evaluated between adjacent wells (multiple-well test) or at some distance from the pumping well depending on the aquifer conditions and drawdown.

Because of the logistics of discharge containment and waste handling, pumping tests are generally limited at the Hanford Site to areas with minimal to no groundwater contamination.

5.4 GEOPHYSICAL INVESTIGATIONS

Geophysical methods, including HRR and borehole methods, will be performed to assess potential future groundwater impacts from vadose zone contaminants. Specifically, these geophysical methods will be used to better define extent and distribution and possibly movement of subsurface contaminants adjacent to known surface discharges or inadvertent releases. Table 5-7 provides the geophysical methods and locations used during the RI.

5.4.1 High-Resolution Resistivity

HRR measures the electrical resistance of soils and is capable of profiling moisture and conductive contaminants in vadose zone soils. Surface-based HRR is capable of interrogating depths as great as 91 m (300 ft) in Hanford Site-type soils, and the results are affected by cultural noise and variations in lithology, moisture, and the nature of the contamination. Sensitivity is dependent on the resistive contrast between contaminated and unaffected sediments. Surface HRR has been demonstrated at the BC Cribs and the T Tank Farm with favorable results.

Investigations using HRR are planned for the vicinities of the WMA-B/BX/BY Tank Farm and the WMA-C Tank Farm. Although these investigations are not intended to directly support the RI for the 200-BP-5 Groundwater OU, information will be useful for assessing potential future groundwater impacts from vadose zone contaminants at these locations.

5.4.2 Borehole Methods

Each borehole will be logged using S. M. Stoller Corporation's spectral-gamma logging system survey and neutron moisture logging system. In general, borehole logging will be performed through a single string of casing (i.e., before telescoping) over the entire length of borehole. The spectral-gamma logging system survey uses a cryogenically cooled, high-purity germanium detector to detect, identify, and quantify gamma-emitting radionuclides in the subsurface. Identification of naturally occurring and gamma-emitting radionuclides is based on detection of characteristic gamma rays emitted during decay of specific radionuclides. The spectral-gamma logging system survey is calibrated annually by measuring detector response to gamma rays from K-40, Th-232, and U-238, resulting in a continuous detector response function over an energy range between 185 keV and 2.6 MeV. Verification of annual calibration before logging will ensure reliable detection and quantification of gamma-emitting radionuclides. The spectral-gamma logging system survey will be operated in move/stop/acquire mode with count times on the order of 100 to 200 seconds per data point, at 0.3 m (1 ft) depth increments. The logging data will be corrected for dead time, well-casing thickness, and the presence of water in the borehole.

The neutron moisture logging system uses a 50 mCi americium/beryllium source and helium-3 detector. Neutrons emitted from the source bombard the surrounding formation and are scattered back to the detector. Neutron moisture logs are useful as an indication of in situ moisture content and for stratigraphic correlation. The neutron moisture logging system will be calibrated to provide an indication of the volumetric moisture content up to about 20 percent in 15.2 and 20.3 cm (6- and 8-in.)-diameter cased boreholes. For other borehole diameters, the neutron moisture logging system data will be used qualitatively to identify differences in moisture content.

5.5 MONITORING OF EXISTING AND NEW WELLS

DOE/RL-2001-49, *Groundwater Sampling and Analysis Plan for the 200-BP-5 Operable Unit*, lists the wells currently included in the 200-BP-5 Groundwater OU monitoring network, the current analytical suites, and the sampling frequency. The planned 15 wells for the RI will be added to the groundwater-monitoring network as each is completed.

Changes to the sampling frequency for selected existing wells will be required to support the RI objectives. The selected frequency will depend on how many times a well has been sampled in the past. The 15 new RI wells will be sampled quarterly the first year after installation, semiannually the second year after installation, then annually indefinitely. Biennial or triennial sampling is performed for perimeter wells that have shown stable trends for several years. Similarly, if a near-field well (i.e., a well proximate to a known waste site) begins to show stable concentrations, the sampling frequency may decrease. If irregular or increasing trends appear, the sampling frequency may increase accordingly.

In addition to changes in sampling frequency, additional analytes will be added to the analytical suite for the existing monitoring wells to coincide with the 200-BP-5 Groundwater OU COPCs developed during the 200-BP-5 Groundwater DQO process (WMP-28945). The implementation strategy to obtain information regarding these additional COPCs is to sample specific near-field wells in high-concentration areas of the plumes and/or at wells immediately downgradient from selected waste sites. The results of the initial sampling will be evaluated and if any of the new analytes are detected above background concentrations, then a new sampling plan will be developed. The COPCs not detected above background in the evaluation wells will be retained as an analyte to be sampled on a 3-year frequency (based on professional judgment) to allow evaluation of potential emerging groundwater contamination.

Table B-1 in Appendix B presents the wells that have been chosen for sampling. These wells will be analyzed for all of the 200-BP-5 Groundwater OU COPCs in accordance with the methods identified in the SAP (Appendix A). It should be noted that various issues may preclude sampling one or more wells and that sampling wells other than those listed in Table B-1 may be required as additional data are obtained.

5.6 SUPPLEMENTAL DATA

The data resulting from the implementation of the DQO process may be supplemented by information derived from other groundwater and vadose zone investigations performed onsite pursuant to projects under requirements for CERCLA, RCRA, and DOE O 435.1, *Radioactive Waste Management*. This supplemental information includes, but is not limited to, the following:

- Sampling and analysis activities required to perform assessments, corrective actions, RFI/CMS, and monitoring sites under RCRA; collection of water-level measurements
- Collection of pH, temperature, and conductivity readings

- Implementation of QA activities (e.g., Washington State Department of Health co-sampling)
- Possibly research activities.

This supplemental data may be used to help refine the CSM and to provide information regarding contaminant movement through the vadose zone. Water-level measurements, specific conductivity readings, temperature, and pH are RCRA sampling parameters that directly complement CERCLA sampling activities. Other measurements (e.g., radionuclide and hazardous chemical concentrations) provide "data of opportunity" and will be integrated into CERCLA evaluations, as appropriate.

An integrated project team has been developed to integrate and coordinate all groundwater and vadose zone investigations concerning the uranium and Tc-99 plumes in the vicinity of the WMA-B/BX/BY Tank Farm and surrounding cribs, trenches, french drain, and reverse well waste sites. The integrated project team consists of technical project leads from the DOE and its major subcontractors.

The integrated project team meets regularly and is responsible for maintaining an integrated plan and schedule for all groundwater and vadose zone investigations, reports, and actions. This type of integration will ensure coordination of field investigations and sharing of information and data.

5.7 DATA EVALUATION

Data evaluation is a key component to the RI/FS process. General guidance to data evaluation is found in EPA/540/1-89/002, *Risk Assessment Guidance for Superfund (RAGS), Volume I -- Human Health Evaluation Manual, (Part A) Interim Final* and DOE/RL-91-45, *Hanford Site Risk Assessment Methodology*. Data evaluation will occur before using data to update the CSM and before incorporating the data into the baseline risk assessment during the RI or remedial alternative evaluation during the FS. The RI data will be organized and evaluated using the following nine steps (EPA/540/1-89/002).

1. Sort data by sample media.
2. Evaluate the analytical and field data-collection methods used.
3. Evaluate the quality of data with respect to sample quantitation limits and data uncertainty.
4. Evaluate the quality of data with respect to qualifiers and codes.
5. Evaluate the quality of data with respect to blanks.
6. Evaluate tentatively identified compounds.
7. Compare potential site-related contamination with background.

8. Develop a set of data for use in the risk assessment.

9. If appropriate, further limit the number of contaminants to be carried through the risk assessment.

Preliminary Conceptual Model Update

The conceptual model for the site is the organizational information framework for describing geology, hydrogeology, geochemistry, and contaminant characterization of the 200-BP-5 Groundwater OU. The conceptual model will be refined by the information generated from the work plan activities. A report is planned to describe in detail the conceptual model or models based on the historic and current data being collected during the RI. The updated conceptual model will provide the framework for the baseline risk assessment and the feasibility tasks associated with remedial alternative development and evaluation.

5.8 GROUNDWATER MODELING

An analysis and modeling approach that is capable of estimating the flow of water and contaminants in the 200-BP-5 Groundwater OU will be used to support the decision process leading to the development and evaluation of remedial alternatives. Information gathered from past disposal waste-site investigations will be evaluated and potentially integrated with the current vadose zone investigations as part of the analyses. This process will be an integrated activity with other OUs. Input values for the groundwater analyses also will be developed from actual past and current field data. In addition, other field studies, and/or published (literature) values that pertain to the Hanford Site, may be used.

The analysis and modeling will consist of the following activities:

- Compilation and evaluation of data
- Identification of currently impacted groundwater
- Interpretation of historic groundwater flow directions and rates
- Evaluation of historic contaminant transport
- Assessment of likely future flow directions and rates
- Evaluation of likely future contaminant migration
- Scoping of potential remedial scenarios and recommendations for analyses to be used through the lifecycle of the decision and remedy process
- Evaluation of the impact of principal assumptions.

An initial evaluation is planned to begin at the conclusion of the conceptual model report in FY 2009. Any recommendations regarding appropriate analysis and modeling approaches will be presented to, and discussed with, the Tri-Parties (DOE, EPA, and Ecology) before implementation.

5.8.1 Saturated Zone Properties

A set of specific parameters for sediment and groundwater has not yet been identified for the baseline modeling associated with the 200-BP-5 Groundwater OU. The potential parameters in this section are based on those that were developed in the past for this and other groundwater OUs at the Hanford Site. Parameters such as K_d, K_h, particle size, and cation-exchange capacity collected from completed wells are useful for modeling contaminant movement and evaluating remedial alternatives. Additional data also are being obtained from the new wells planned as part of this work plan. In addition, depth-discrete groundwater data (i.e., analytical sampling and hydrogeologic data) are being collected from both existing wells and new boreholes as they are drilled. The depth-discrete data also are useful for selecting screen intervals for new wells.

5.8.2 Saturated Zone Sediment Parameters

Specific saturated zone parameters that are being collected for the 200-BP-5 Groundwater OU are listed in Table 5-8. The parameters presented in Table 5-8 include geophysical, hydraulic transport, and geochemical. The geophysical included particle size, calcium carbonate content, bulk density, and lithology. The hydraulic and transport include effective porosity, particle density, total porosity, and saturated K_h. The geochemical includes K_d for key contaminants, major cations (i.e., sodium and calcium), cation-exchange capacity, contaminant concentrations, and isotopic concentrations. In addition, slug and pumping tests are planned to further refine the following hydraulic parameters: effective porosity, specific yield, specific storage, transmissivity, and K_h.

5.8.3 Groundwater Parameters

Table 5-8 lists hydraulic and geochemical parameters that will be collected for groundwater samples. When new wells are drilled in the 200-BP-5 Groundwater OU, some of these data will be obtained from depth-discrete groundwater samples during drilling. The following hydraulic parameters for groundwater modeling and/or evaluation of remedial alternatives are included: hydraulic gradient, transmissivity, K_h measured during slug tests, groundwater production rates, water-level drawdown, groundwater pumping performance during well development, and longitudinal and transverse dispersivity. The following geochemical parameters also are potential inputs for groundwater modeling and/or remedial alternatives evaluation: major cations (i.e., sodium and calcium), K_d, specific conductance, total organic carbon, total inorganic carbon, pH, temperature, alkalinity, dissolved oxygen, and turbidity.

5.9 REMEDIAL INVESTIGATION REPORT

The RI report provides a summary of all site investigations conducted within the OU. The RI report includes analyses of the ongoing activities, data collection performed as part of interim measures, and data generated as a result of the activities performed as described in this work plan. The data will include not only the analytical results from evaluation of vadose zone sediment, aquifer sediments, and groundwater samples, but also the output from groundwater modeling conducted using the inputs from hydrogeologic data collected as described in this work plan. The RI report will include a summary of the data, which will provide the basis for reaching some conclusions about the nature and extent of contamination within the OU, as well as the potential for future contamination and migration pathways. The RI report will integrate the data and provide the baseline risk assessment necessary for the OU.

5.10 BASELINE RISK ASSESSMENT

The baseline risk assessment for the 200-BP-5 Groundwater OU will be conducted following RI data collection and evaluation. The baseline risk assessment will evaluate the current and potential threats to human health and the environment posed by contaminants remaining in the soil, leaching through soil, migrating to groundwater, and potentially migrating to surface water. The preliminary CSM introduced in Sections 3.1 and 3.5 represents the framework for evaluating risk associated with the 200-BP-5 Groundwater OU. The preliminary CSM portrays the current understanding of source, pathway, and receptor for the 200-BP-5 Groundwater OU. The preliminary CSM will be updated as data are gathered during the RI and generated from supplementary sources (i.e., source OU and RCRA TSD unit investigations).

The baseline risk assessment will involve a human-health risk assessment consisting of the following four main steps:

- Exposure assessment
- Toxicity assessment
- Risk characterization
- Uncertainty analysis.

Each of these steps is briefly described below, and the information is consistent with EPA/540/1-89/002.

Ecological risk also will be considered; however, existing information and analysis indicate that the exposure pathways from groundwater to terrestrial ecological receptors in the 200 Areas are incomplete. The ecological risk to receptors in the Columbia River environment (riparian zone and river) will be evaluated as applicable.

Risk management decision makers will use the results of the baseline risk assessment to develop remedial action objectives specifying the contaminants of interest, exposure pathways, and preliminary remediation goals. The preliminary remediation goals will be developed on the basis of chemical and radionuclide-specific applicable or relevant and appropriate requirements, the site-specific risk assessment, and other available information.

5.11 FEASIBILITY STUDY

The information from the RI and baseline risk assessment will be used to execute the FS in three phases: (1) develop alternatives, (2) screen alternatives, and (3) perform detailed analyses of alternatives. The RI/FS process for the 200-BP-5 Groundwater OU has been scoped in accordance with the requirements of 40 CFR 300.430(b), "Remedial Investigation/Feasibility Study and Selection of Remedy." In fulfillment of the requirements to "identify likely response scenarios," the FS will identify and evaluate a range of alternatives that include the following.

- Restore groundwater to its highest beneficial use everywhere within the plume boundary, within a reasonable restoration timeframe, by implementing one or more potentially applicable technologies.
- If it is determined that it is not technically practicable to restore the groundwater to its highest beneficial use, then corresponding MCLs shall be attained where relevant and appropriate to the circumstances of the release by implementing one or more potentially applicable remedies.

5.12 ALTERNATIVES DEVELOPMENT

Groundwater remediation in the 200-BP-5 Groundwater OU is dictated by CERCLA regulations, as provided in 40 CFR 300, Subpart E, "Hazardous Substance Response." General response actions will be developed that may include, but are not limited to, the following remedial alternatives. These actions may be taken singly or in combination (e.g., pumping and ex situ treatment of groundwater) to satisfy the remedial action objectives for the 200-BP-5 Groundwater OU. Each of these alternatives is discussed in the following subsections:

- No action
- Institutional controls
- Monitoring natural attenuation
- Permeable or impermeable containment
- Pump-and-treat
- Potential future alternatives.

Groundwater volumes or areas will be identified to which general response actions might be applied. The FS will identify and screen technologies applicable to reach general response actions to eliminate those that cannot be implemented technically at the site. The general response actions will be further defined to specify remedial technology types (e.g., chemical versus biological in situ treatment).

Technology process options will be identified and evaluated in order to select a representative process for each technology type retained for consideration. The first phase of the FS will be completed by assembling the selected representative technologies into alternatives representing a range of treatment and containment combinations, as appropriate.

5.12.1 No Action

The National Contingency Plan (40 CFR 300) requires that a no-action alternative be evaluated as a baseline for comparison with other alternatives. The no-action alternative represents a situation where no restrictions, controls, or active remedial measures are applied to the 200-BP-5 Groundwater OU. No action implies a scenario of walking away from the site and taking no measures to monitor or control contamination. The no-action alternative requires that a site pose no unacceptable threat to human health and the environment. Current information indicates that some form of action is required.

5.12.2 Institutional Controls

Institutional controls refer to physical and/or legal barriers to prevent access to contaminants and are combined with some level of monitoring. Institutional controls usually are required when contamination is left in place above cleanup levels.

Physical methods of controlling access to groundwater are access controls, which include signs, entry control, artificial or natural barriers, and active surveillance. Physical restrictions are effective in protecting human health by reducing the potential for contact with contaminated media and avoiding adverse environmental, worker safety, and community safety impacts that arise from the potential release of contaminants. If used alone, however, physical restrictions are not effective in achieving containment, removal, or treatment of contaminants. They also require ongoing monitoring and maintenance.

Legal restrictions include both administrative and real-property actions intended to reduce or prevent future human exposure to contaminants remaining within the aquifer by restricting the use of the groundwater. Land-use restrictions and controls on real-property development are effective in providing a degree of protection for human health by minimizing the potential for contact with contaminated media. Restrictions can be imposed through land covenants, which would be enforceable through lawsuits by the United States, under Washington State law, and by EPA. They also avoid adverse environmental, worker safety, and community safety issues that could arise from the potential release of contaminants associated with other remedial technologies (e.g., treatment). Land-use restrictions are somewhat more effective than access controls if control of a site transfers from RL to another party because they use legal and administrative mechanisms that already are available to the community and the state.

The disadvantages of land-use restrictions are similar to those for access control in that they do not contain, remove, or treat contaminants. Also, land-use restrictions are not self-enforcing. They only can be maintained by an effective system for monitoring land use to ensure compliance with the imposed restrictions.

5.12.3 Monitored Natural Attenuation

MNA describes a range of physical and biological processes that, unaided by deliberate human intervention, reduce the concentration, toxicity, or mobility of chemical or radioactive contaminants. These processes take place whether or not other active cleanup measures are in place. However, techniques and technologies for predicting and monitoring natural attenuation are being developed.

The mechanisms of natural attenuation can be classified as destructive and nondestructive. Destructive processes include biodegradation and hydrolysis. Biodegradation is by far the most prevalent destructive mechanism for groundwater. Biodegradation, also called bioremediation, is a process in which naturally occurring micro-organisms (e.g., yeast, fungi, and bacteria) break down target organic contaminants (e.g., fuels and chlorinated solvents) into less toxic or non-toxic substances. Biological processes (and resulting changes in REDOX/pH) may assist with the conversion of certain metals to different species of the same element; for instance, Cr(VI) may be reduced to Cr(III). Microbes typically metabolize organic compounds in groundwater to survive. This metabolic process alters or destroys the compound. Certain micro-organisms digest fuels, chlorinated solvents, and other substances found in the subsurface environment. Nondestructive attenuation mechanisms include sorption, dispersion, dilution, and volatilization. Dilution, dispersion, and sorption generally are the dominant nondestructive mechanisms for groundwater.

Long-term monitoring is necessary to demonstrate that contaminant concentrations continue to decrease at a rate sufficient to ensure no constituent becomes a health threat or violates regulatory criteria. Monitoring should be designed to verify that potentially toxic transformation products are not created at levels that are a threat to human health; that the plume is not expanding; that there are not releases that could affect the remedy; and that there are no changes in hydrogeological, geochemical, or microbiological parameters that might reduce the effectiveness of natural attenuation.

The EPA provides guidance for use of MNA in EPA/540/R-99/009, *Use of Monitored Natural Attenuation at Superfund RCRA Corrective Action and Underground Storage Tank Sites November 1997*, OSWER 9200.4-17P. This directive identifies three lines of evidence for evaluating MNA:

- Site data that clearly indicate the plume is shrinking or stable before impacting receptors
- Site data that identify the natural attenuation process and rate of these processes relative to reaching remediation goals
- Laboratory or field tests that quantify specific natural attenuation processes and rates.

If site data are insufficient to develop the first line of evidence, then the second and third lines of evidence need to be developed with a sufficient technical basis to support remediation decisions.

If MNA is selected as the remedy, it is implemented using a monitoring plan designed to verify that natural attenuation processes continue to attenuate the plume and that remediation goals are met over time.

Accelerated natural attenuation is another alternative that will be evaluated. This alternative uses a metals remediation compound for accelerating in situ metals cleanup in groundwater systems. One method of accelerating natural attenuation is through metals immobilization, where highly mobile metals in the aqueous phase are transferred to a solid, stable phase that becomes part of the soil. The most common mechanisms of in situ metals immobilization are metals absorption to soil particles or precipitation of metal solids that are chemically fixed to soil particles.

5.12.4 Permeable or Impermeable Containment

The intent of the permeable or impermeable containment alternative is to contain groundwater contamination through the use of either permeable or impermeable subsurface barriers. The deep aquifer found in the majority of the 200-BP-5 Groundwater OU likely limits emplacement of subsurface barriers through closely spaced wells rather than the more effective trenching methods.

Permeable reactive barrier technology treats contaminants as they pass through a treatment zone. Knowledge of contaminant plume location and groundwater flow paths is essential for the technology to be effective. The permeable reactive barriers may act on contaminants by destroying the contaminant in a reaction (either biologic or abiotic), by adsorption of the contaminant onto the permeable reactive barrier media, or by precipitation resulting from a chemical reaction (PNNL-15917, *Screening of Potential Remediation Methods for the 200-BP-5 Operable Unit at the Hanford Site*).

The permeable reactive barrier technology may be implemented as a funnel-and-gate system or an interception wall. The funnel-and-gate system uses physical barriers (e.g., sheet pilings or clay or grout on two sides) to direct groundwater and the contaminant plume flow through a permeable treatment zone. An interception wall is a continuous treatment zone that has sufficient width to intersect a contaminant plume. Five types of permeable reactive barriers will be evaluated (PNNL-15917):

- In situ REDOX manipulation technology
- Zero-valent iron
- In situ anerobic bioremediation
- Injectable apatite
- Injectable polyphosphate.

Impermeable barriers are designed to restrict the movement of groundwater, thereby preventing the spread of contaminants through groundwater flow. Impermeable barriers that could be considered include cryogenic coil barrier, sheet piling or grout curtain, or creating a groundwater mound using injected clean water.

A specific type of cryogenic technology involves freezing soil porewater to create a frozen soil barrier (DOE/EIS-0222-F, *Final Hanford Comprehensive Land-Use Plan Environmental Impact*). A series of subsurface heat transfer devices, or thermoprobes, are installed around a contaminant source. The thermoprobes use liquid-to-gas phase change of a passive refrigerant (carbon dioxide) to remove heat from the surrounding sediment. The refrigerant is supplied through interconnected piping from aboveground refrigeration units. The system is insulated, and a waterproof membrane is installed at the ground surface; these measures prevent heat gain from the surface and minimize infiltration.

Sheet piling or a grout curtain could be designed as an independent alternative or in combination with a permeable barrier. In the former case, sheet piling or a grout curtain could be used to channel groundwater toward a permeable barrier. In the latter case, sheet piling or a grout curtain could be used by itself to create an impermeable barrier that would trap the plume, preventing migration.

An injectable grout wall is a specific type of impermeable barrier that is installed by jet-grouting from an injection well. Jet-grouted walls are constructed by injecting grout at high pressures (up to 6,000 lb/in^2) into multiple, closely spaced holes to form a horizontally continuous barrier (PNNL-15917).

Finally, an artificial hydraulic mound could be achieved by injecting clean water into a number of injection wells installed downgradient of the contaminant plume. The hydraulic mound would, in effect, create a wall that would contain the plume.

5.12.5 Pump-and-Treat

The pump-and-treat alternative entails the design and implementation of an onsite 200-BP-5 Groundwater OU pump-and-treat system to accelerate removal and decrease the size of contaminant plumes. The objective of the pump-and-treat system would be to capture the groundwater contaminant plume using extraction wells to prevent further contaminant migration, treat the extracted water onsite, and then reinject the treated water upgradient of the plume.

This alternative would evaluate the option of using one or more agents to assist in mobilizing selected contaminants (lixiviant), then capturing the contaminants with the downgradient extraction wells.

The pump-and-treat alternative also would evaluate the option of installing an aboveground IX treatment system to remove soluble metal species (e.g., cesium, cobalt, plutonium, strontium, and technetium contaminants) from the extracted groundwater. The extracted groundwater is pre-filtered and then pumped through a series of two or more beds (IX columns) of adsorbent where the ionic species in the groundwater exchange with or are adsorbed onto the surface of the adsorbent, thereby removing them from solution (DOE/RL-91-45).

This alternative would need to be supported by groundwater modeling to define the optimum location for the extraction wells and to ensure that the plume is fully captured. This alternative would require treatment filter regeneration and/or disposal.

5.12.6 Potential Future Technology Development

New remediation technologies will be considered during the course of the 200-BP-5 Groundwater OU RI/FS process.

5.13 TREATABILITY STUDIES

Results of two prior pilot-scale treatability tests in the 200-BP-5 Groundwater OU will be incorporated into the technology evaluation process during the FS. Pump-and-treat groundwater pilot-scale treatability tests were conducted from August 1994 through May 1995 at two locations within the 200-BP-5 Groundwater OU: the 216-B-5 Reverse Well multiple-plume site, and the BY Cribs multiple-plume site. These two locations were identified for pilot-scale treatability testing in DOE/RL-92-19, because of the presence of what were considered high-priority contaminant plumes. The treatability testing was the result of implementation of an accelerated action along with either an expedited response action or an interim remedial measure pathway, in accordance with the CERCLA process.

The two tests incorporated the use of an aboveground IX treatment system to remove soluble metal species (e.g., cesium, cobalt, plutonium, strontium, and technetium contaminants) from the extracted groundwater. At the 216-B-5 Reverse Well site, Cs-137, Pu-239/240, and Sr-90 contaminant plumes were present within proximity (i.e., within 91.4 m [300 ft]) of the 216-B-5 Reverse Well. At the BY Cribs site, Co-60, Tc-99, cyanide, and nitrate contaminant plumes had migrated from the BY Cribs (source area) northward toward Gable Gap (DOE/RL-91-45).

The 216-B-5 Reverse Well pilot-scale treatment test consisted of three IX columns in a series-flow arrangement: a bone-char column, followed by a clinoptilolite column, then followed by a mixed-bed column with 50 percent bone char and 50 percent clinoptilolite.

The 216-B-5 Reverse Well treatment system performed satisfactorily for removal of Cs-137, Pu-239/240, and Sr-90. Cesium-137 and Pu-239/240 could be removed to below MCL levels by IX, and Sr-90 closely approached but could not achieve its MCL in the effluent.

Aquifer pumping provided sufficient quantities of groundwater containing significant concentrations of Cs-137 and Sr-90. However, extracted groundwater concentrations of Pu-239/240 were small relative to the quantities of Pu-249/240 discharged through the reverse well into the surrounding sediments, which confirmed that soil adsorbs plutonium to the extent that the groundwater is not excessively impacted.

Because both the Cs-137 and Sr-90 decay to negligible levels long before the plumes migrate from the Central Plateau, and because Pu-239/240 is essentially immobile, the future risks were considered low at the 216-B-5 Reverse Well site. Therefore, the treatability test was discontinued at this site (DOE/RL-91-45).

The BY Cribs pilot-scale treatment test consisted of two IX columns in a series-flow arrangement. A strong-base anion IX resin was selected for evaluation because the cobalt and technetium were believed to be in anionic form.

The IX treatment system performed satisfactorily in removing elevated concentrations of Co-60 and Tc-99 at the BY Cribs site. However, the relatively low groundwater extraction rates at this site underscored the high degree of uncertainty concerning plume geometry and aquifer characteristics. For this reason, the treatability test was discontinued at this site (DOE/RL-91-45).

5.14 FEASIBILITY STUDY REPORT

The FS report will document the detailed analysis of alternatives using the following nine evaluation criteria:

- Two threshold criteria
  - Overall protection of human health and the environment
  - Compliance with applicable or relevant and appropriate requirements
- Five primary balancing criteria
  - Long-term effectiveness and permanence
  - Reduction of toxicity, mobility, or volume through treatment
  - Short-term effectiveness
  - Implementability
  - Cost
- Two modifying criteria
  - State acceptance
  - Community acceptance.

5.15 PROPOSED PLAN AND COMMUNITY INVOLVEMENT

5.15.1 Proposed Plan

The proposed plan will identify a preferred alternative and present the alternative to the public for review and comment. The proposed plan also will provide a summary of the investigations for the 200-BP-5 Groundwater OU, the data generated from the various investigations, and the conclusions derived from the data. The proposed plan will summarize the results of the FS and the basis for the action(s) proposed to be taken to remediate the site. It will include a summary of the remedial action and a schedule for implementation.

5.15.2 Community Relations

The *Tri-Party Agreement Community Relations Plan* (RL, 2002) outlines the public participation processes implemented by the Tri-Parties under authority of the Tri-Party Agreement and identifies several ways the public can participate in the Hanford Site cleanup decision-making process. These participation outlets include contact information, how to obtain publications on the Hanford Site cleanup activities, news media activities, and public involvement and comment. The plan is available on the Internet at http://www.hanford.gov/?page=113&parent=91 .

The Tri-Parties conduct public involvement and information activities both cooperatively and independently. The Community Relations Plan intends to fulfill applicable state and Federal laws regarding the development of community involvement and public participation plans. The plan also serves as one of the overall public participation plans guiding public involvement at the

Hanford Site. Additional project-specific public participation plans are developed as needed at the Hanford Site. For the 200-BP-5 Groundwater Project, a project-specific community relations plan is not planned.

In the CERCLA process (Figure 5-7), the proposed cleanup plan must undergo a 30-day public comment period before a decision is made. A public meeting may be requested on the plan during the comment period by contacting the Hanford Cleanup Line at 1-800-321-2008.

This document will be placed in information repositories as listed in the Community Relations Plan.

Figure 5-1. 200-BP-5 Groundwater Operable Unit Project/Task Organization.

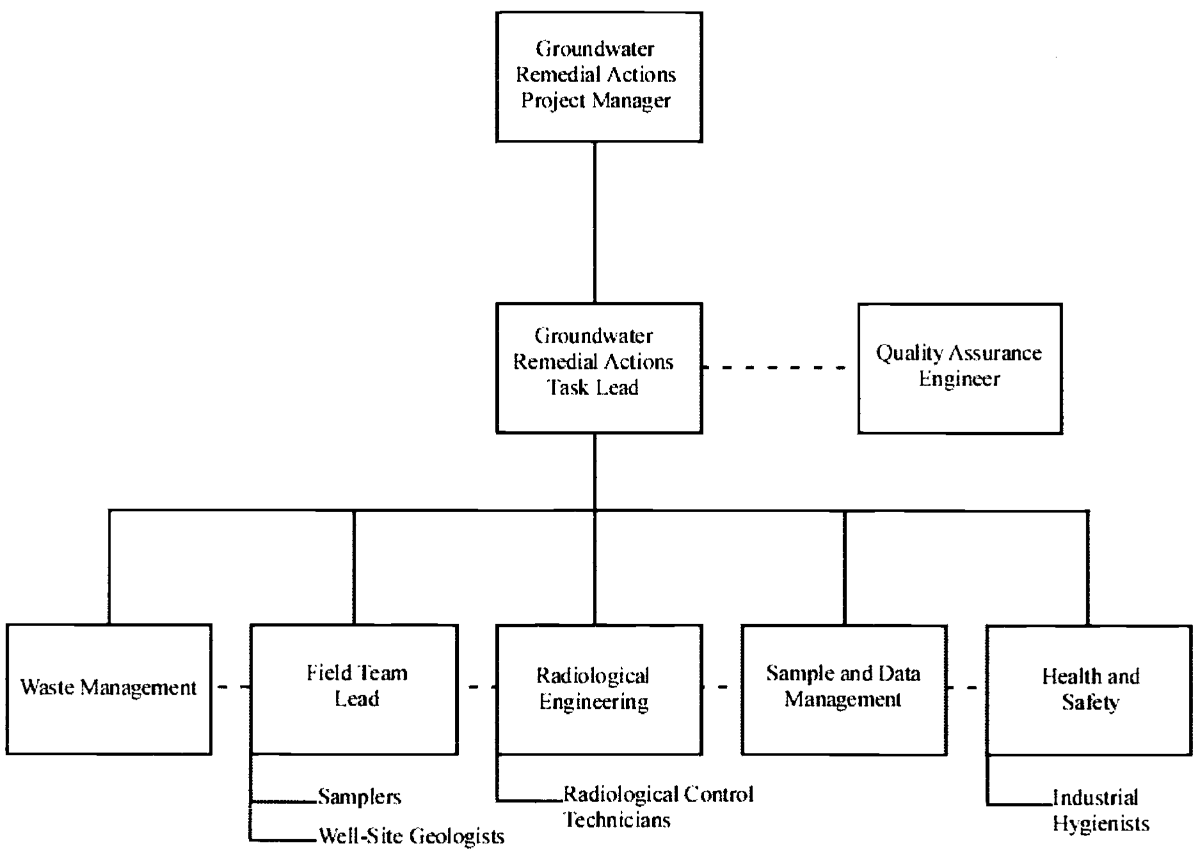

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Figure 5-2. Map Showing Proposed Well Locations and Groundwater Plumes in Sub-Area #3.

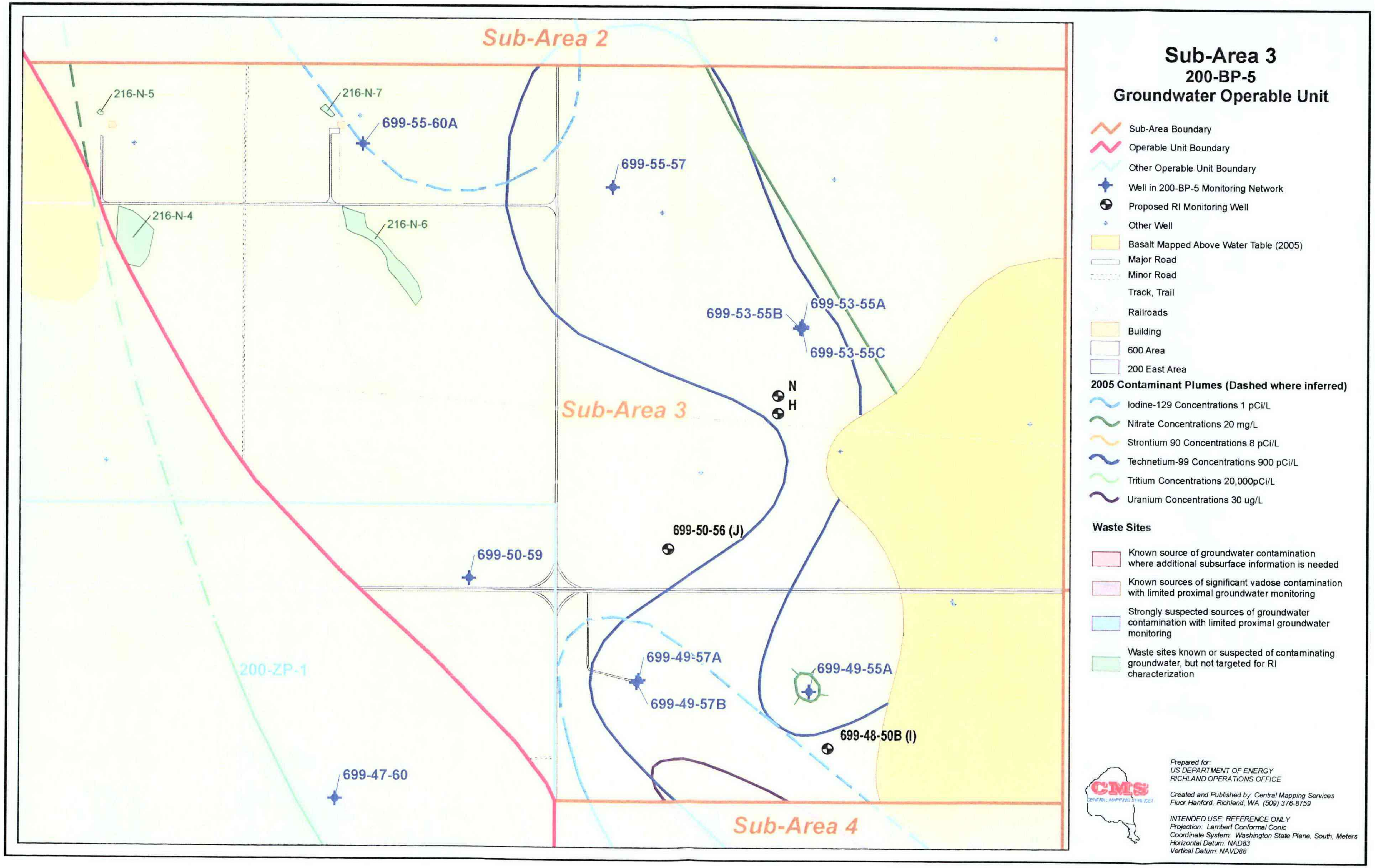
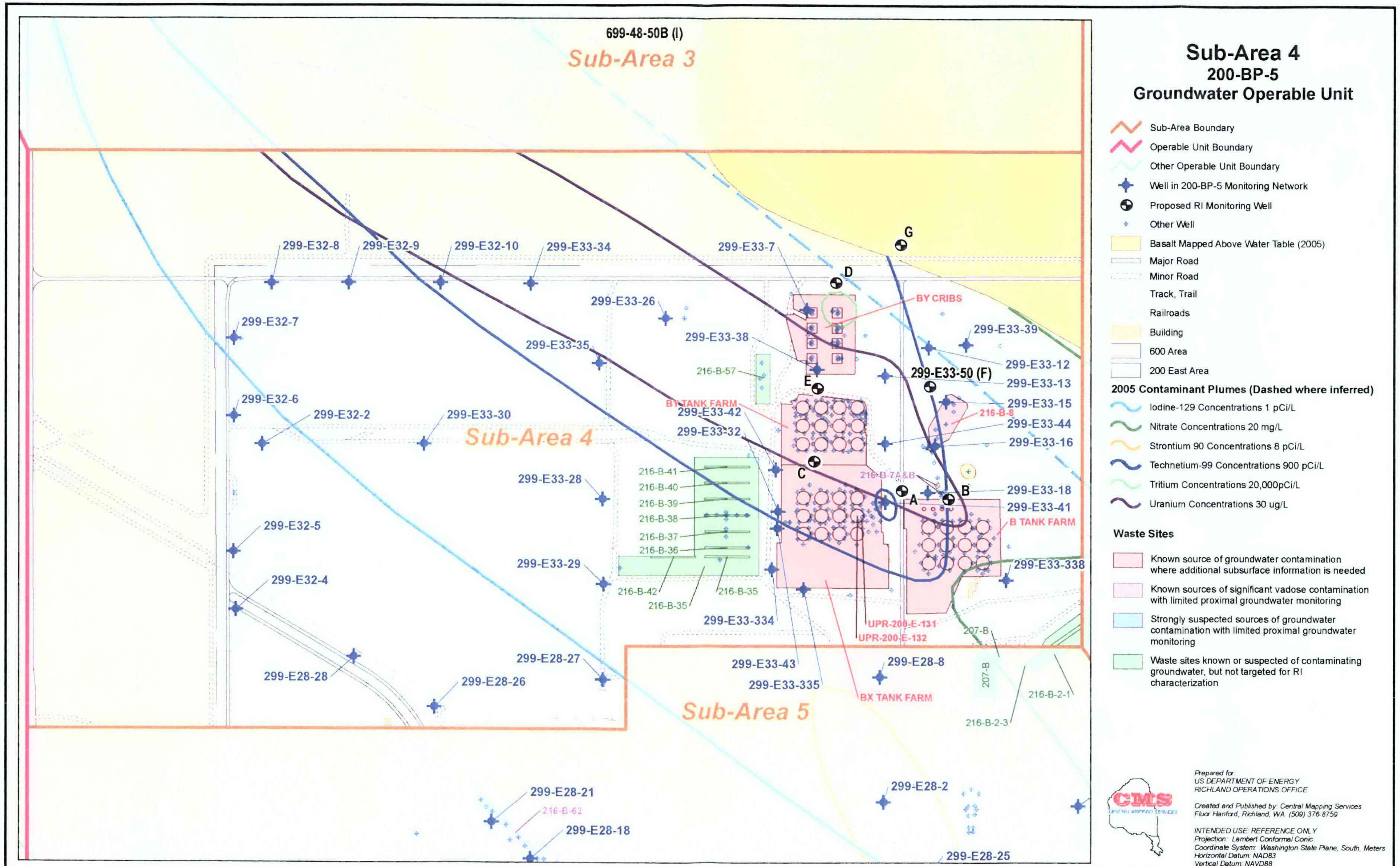
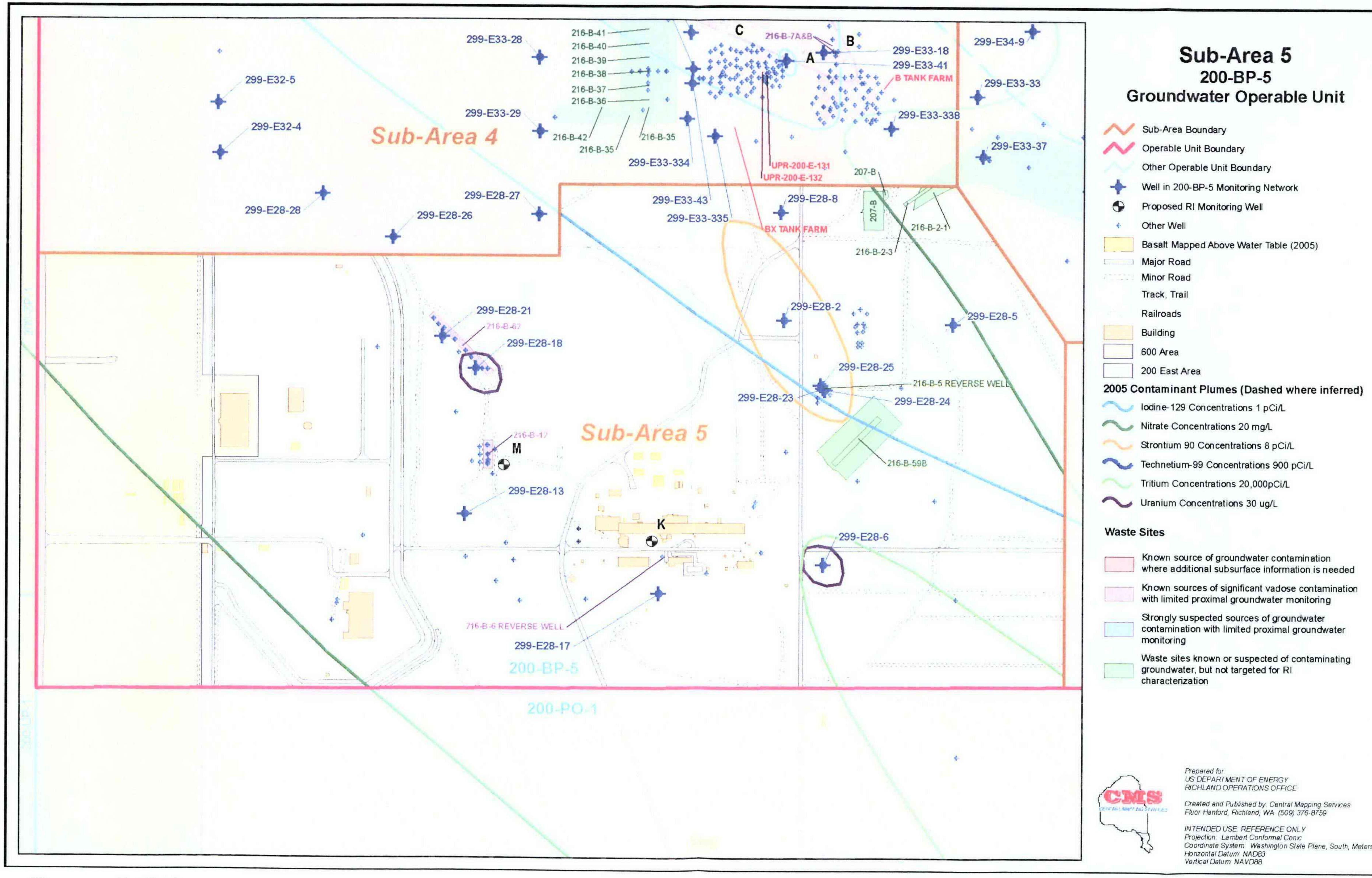


Figure 5-3. Map Showing Proposed Well Locations and Groundwater Plumes in Sub-Area #4.



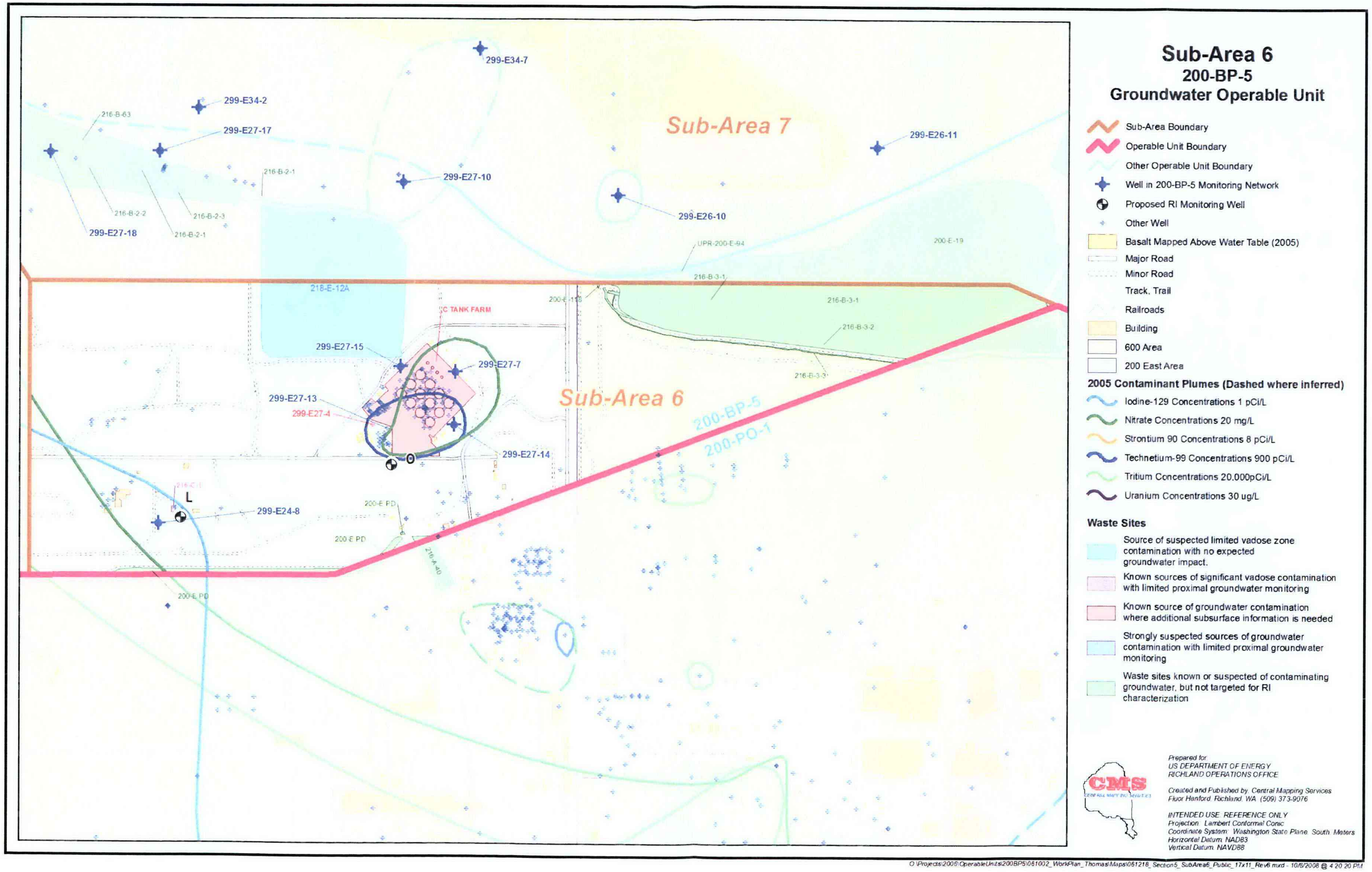
ID = identification number.
LLWMA = low-level waste management area.
UPR = unplanned release.

Figure 5-4. Map Showing Proposed Well Locations and Groundwater Plumes in Sub-Area #5.



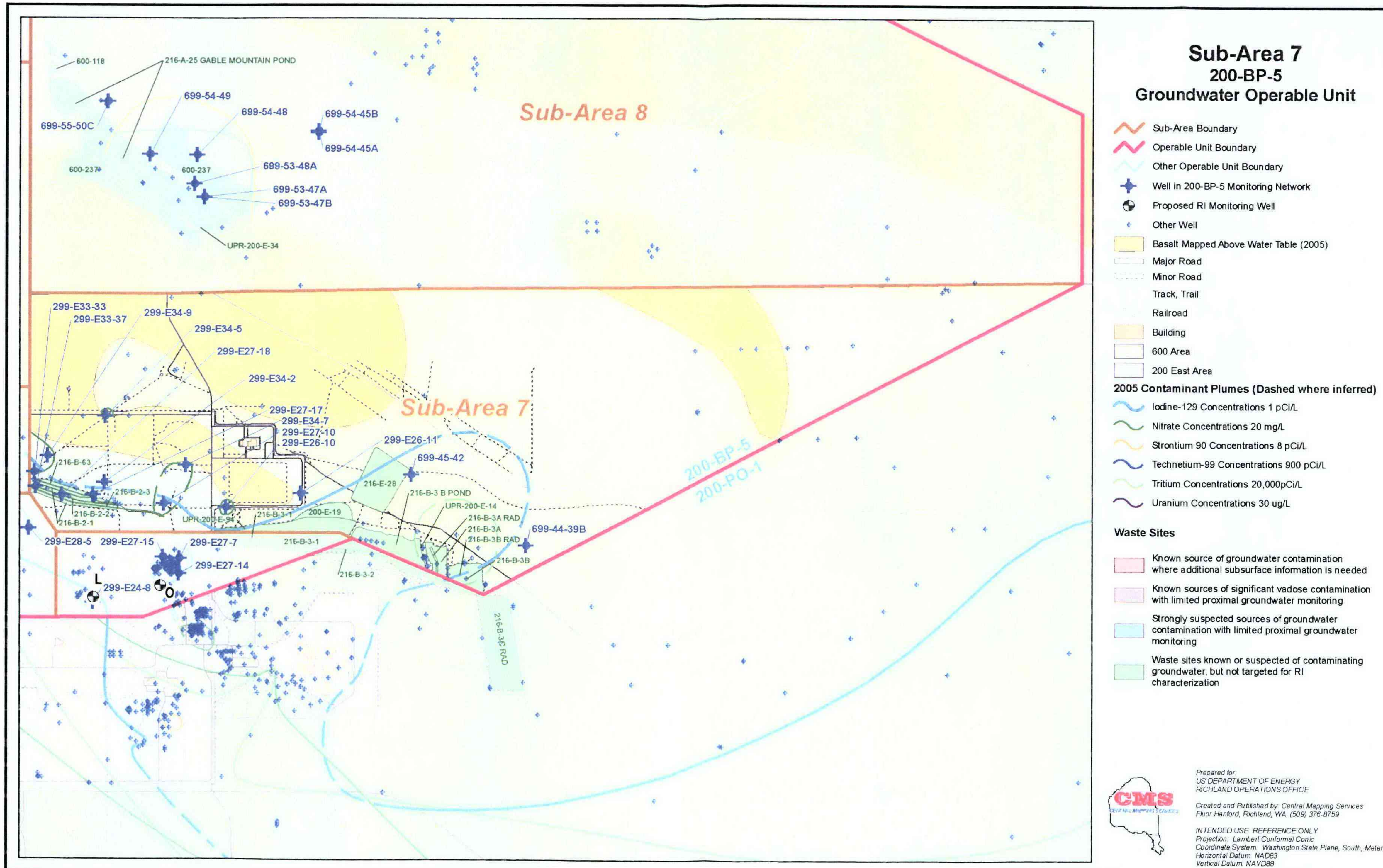
ID = identification.
LLWMA = low-level waste management area.
UPR = unplanned release.

Figure 5-5. Map Showing Proposed Well Locations and Groundwater Plumes in Sub-Area #6.



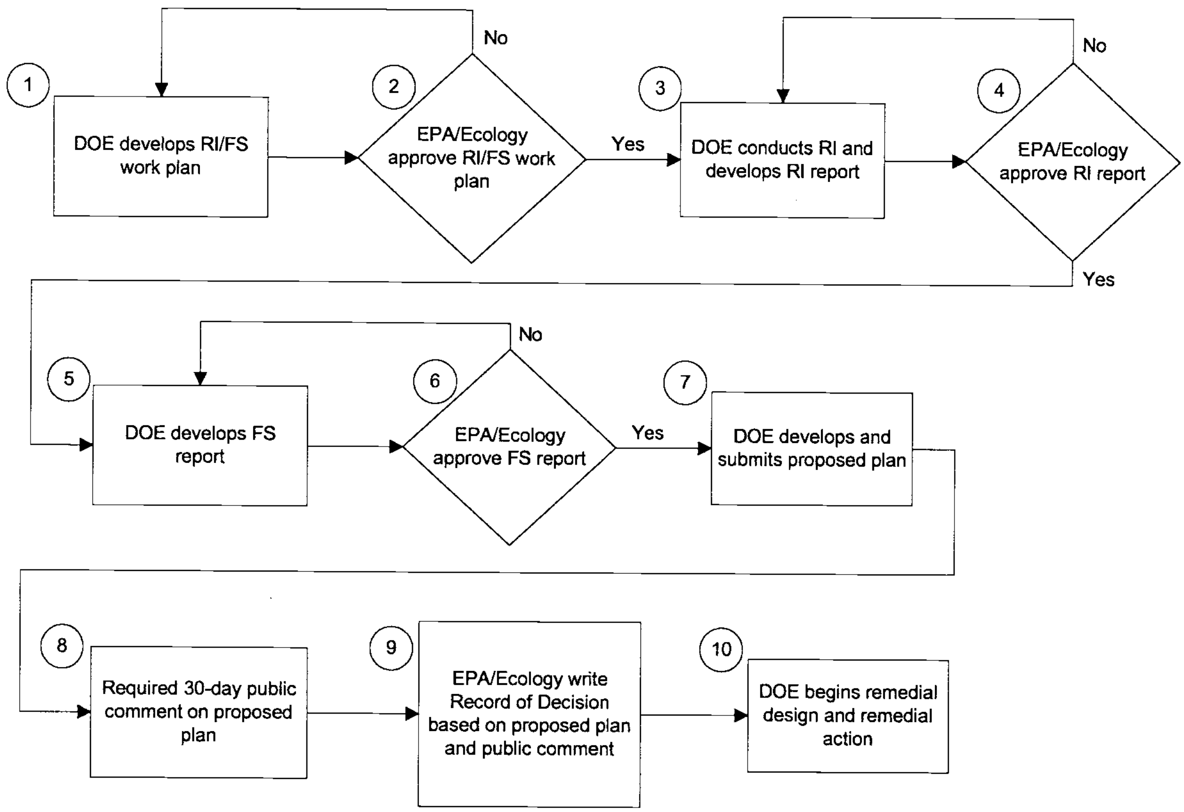
RI = remedial investigation.
UPR = unplanned release.

Figure 5-6. Map Showing Proposed Well Locations and Groundwater Plumes in Sub-Area #7.



DOE = U.S. Department of Energy.
ID = identification.
LERF = Liquid Effluent Retention Facility.
LLWMA = low-level waste management area.
UPR = unplanned release.

Figure 5-7. Tri-Party Agreement *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* Remedial Investigation/Feasibility Study Decision Process.



From RL, 2002, *Tri-Party Agreement Community Relations Plan*.

DOE = U.S. Department of Energy.
Ecology = Washington State Department of Ecology.
EPA = U.S. Environmental Protection Agency.
FS = feasibility study.
RI = remedial investigation.
RI/FS = remedial investigation/feasibility study.

Table 5-1. Location Information for Planned and Contingency Wells.

Well Identification	Location by Sub-Area	Figure Number
"A," "B," "C," "D," "E," "F," and G"	4	5-3
"H," "I," "J," and "N"	3	5-2
"K"and "M"	5	5-4
"L" and "O"	6	5-5

Table 5-2. Primary Rationale for Locations of Planned Wells. (2 Pages)

Well Identification	Primary Rationale for Location
"A"	Positioned between existing wells 299-E33-41 and 299-E33-18 to provide additional information on lateral extent and source of localized uranium contamination in the vadose zone and depth and character of low-permeability strata that might influence vertical and lateral spreading. Proposed location may change depending on results of HRR surveys.
"B"	Positioned east of well 299-E33-18 and west of the 216-B-7A Crib to provide information on lateral migration and source of vadose zone contaminants (particularly uranium) near the 216-B-7A Crib and the B Tank Farm and allow depth-discrete groundwater samples in the aquifer to evaluate vertical contaminant distribution. This well potentially could be used as an extraction well if pump-and-treat were determined to be the most feasible alternative for remediation of the growing uranium plume. Proposed location may change depending on results of HRR surveys.
"C"	Positioned north of the BX Tank Farm and south of the BY Tank Farm to provide vertical nature and extent of contamination from the assumed cascade line leak between tanks 241-BX-103 and 241-BY-101, and possibly identify lateral extent of contamination from possible spills/leaks associated with tanks 241-BX-106, 241-BX-102, and 241-BY-107. Additional data objectives at this location include identifying depth and character of low-permeability strata in vadose zone and confirming the top of the basalt in the area. Proposed location may change depending on results of HRR surveys.
"D"	Proposed to be installed north of the BY Cribs to provide information regarding the northern extent of vadose zone contamination associated with the BY Cribs and characterize the thinly bedded, low-permeability (and possibly perching) layer observed during prior drilling in the vicinity. This well potentially could be used as an extraction well if pump-and-treat were determined to be the most feasible alternative for remediation of the growing Tc-99 plume. Proposed location may change depending on results of HRR surveys.
"E"	Positioned south of well 299-E33-38 and north of the BY Tank Farm to provide vertical extent of moisture in the vadose zone that is possibly linked with the high chloride concentrations reported in wells in this area. Location also will aid in identifying possible perched or high-moisture zones that may influence lateral spreading of contamination near the northern portion of tank 241-BY-106. The location also is designed to investigate possible deep contamination from the BY Cribs. This well potentially could be used as an extraction well if pump-and-treat were determined to be the most feasible alternative for remediation of the growing uranium plume. Proposed location may change depending on results of HRR surveys.
"F"	Proposed south of well 299-E33-12 to allow monitoring of the Rattlesnake Ridge confined aquifer and to evaluate possible source of contaminants continuously observed in well 299-E33-12 groundwater laboratory analyses.
"G"	If analytical data from well "F" demonstrate no contamination, then well 299-E33-12 will be decommissioned and well "G" would be located downgradient of well 299-E33-12 to confirm proper decommissioning. If well "F" shows that the Rattlesnake Ridge interbed confined aquifer is contaminated, analysis may show there is an upgradient pathway for contaminated groundwater between the unconfined aquifer and the confined aquifer. The location of well "G" likely would be changed if contamination were found at well "F."
"H"	Proposed upgradient of well 699-53-55 to assess potential intercommunication between unconfined and confined aquifers.
"I"	Proposed north of well 299-E33-26 and south of well 699-49-55A to provide northern definition of uranium plume.
"J"	Proposed between wells 699-49-55A and 699-52-57 to resolve contaminant concentrations in the technetium-contoured plume in this area. This well also may help identify an erosional channel in the basalt for potential northern groundwater flow.

Table 5-2. Primary Rationale for Locations of Planned Wells. (2 Pages)

Well Identification	Primary Rationale for Location
"K"	Proposed near the 216-B-6 Reverse Well, south of the B Plant, to determine the extent of contamination in the deep vadose zone and groundwater near this reverse well.
"L"	Proposed near the 216-C-1 Hot Semiworks Plant to investigate possible vadose zone contamination and provide additional groundwater monitoring of waste constituents (particularly chromium, uranium, plutonium, and strontium) associated with past discharges in the area. Location also allows evaluation of elevated nitrate groundwater concentrations observed in the 1960s from wells 299-E27-5 and 299-E24-8.
"M"	Proposed as a replacement for well 299-E28-16 at the 216-B-12 Crib. Only one groundwater well is located near this waste site. This well potentially could be used as an extraction well if pump-and-treat were determined to be the most feasible alternative for remediation of the growing uranium plume.
"N"	Proposed to be installed south of well 699-53-55 to resolve contaminant concentrations in the technetium-contoured plume in this area and determine aquifer hydraulic properties. A primary requirement for this well is to determine vertical variability of technetium and nitrate contamination. This well also is linked with well "H" and is planned to be used for a pump test to determine the potential capture zone for Tc-99. Other possible benefits from this proposed well include providing additional control for the basalt surface, determining the concentrations of other radionuclide and chemical contaminants, and providing additional numerical results to refine statistical measurements for modeling risk of contaminant migration in the future.
"O"	Proposed in the vicinity of the WMA-C Tank Farm. This well will be used to evaluate vertical and horizontal distribution of Tc-99 and nitrate downgradient of WMA-C. Final location of the well will be identified after further evaluation of groundwater flow using borehole deviation surveys and plume geometries in the vicinity.

HRR = high resolution resistivity.
WMA = waste management area.

Table 5-3. Planned Vadose Zone Sediment Samples.

Type of Sample	Sample Frequency	Target Interval[a]	Purpose	Locations
Grab	5 ft	Entire borehole	Geologic archive	All proposed wells
Split-spoon	Continuous for select intervals	Shallow, deep	Physical and geochemical parameters	"A," "B," "C," "D," "E," "F," "K," "L," and "M"
Grab	2.5 ft for select intervals	Shallow, deep	Model development parameters	"A," "B," "C," "D," "E," "F," "I," "K," "L," and "M"
Grab	2.5 ft for select intervals	Deep	Uranium isotope evaluation[b]	"A," "B," "C," "D," "E," "F," "G," "L," and "M"
Grab	2.5 ft for select intervals	Deep	Investigate chromium and nitrate	"K" and "L"

[a] Shallow = ground surface to 100 ft below ground surface; deep = 100 ft to water table.
[b] For the uranium isotope evaluation, boreholes "D," "E," "M," and potentially "L" have shallow target intervals.

Table 5-4. Planned Saturated Sediment Samples.

Type of Sample	Sample Frequency	Target Interval	Purpose	Locations
Split-spoon	select intervals	Unconfined aquifer	Physical and hydrologic parameters	"A," "B," "C," "D," "E," "K," "L," "M," "N," and "O"
Grab	2.5 ft	Unconfined aquifer	Model development parameters	"A," "B," "C," "D," "E," "K," "L," "M," "N," and "O"
Grab	select intervals	Unconfined aquifer	Uranium isotope evaluation	"A," "B," "C," "D," "E," "G," "K," "L," and "M"
Grab	select intervals	Unconfined aquifer	COPC analysis	"A," "B," "C," "D," "E," "K," "L," "M," "N," and "O"
Split-spoon	Top, middle and bottom of interbed	Confined aquifer	Physical and geochemical parameters	"G," and "H"
Grab	2.5 ft	Confined aquifer	Model development parameters	"G," and "H"
Grab	Top, middle and bottom of interbed	Confined aquifer	COPC analysis	"G," and "H"

COPC = contaminant of potential concern.

Table 5-5. Planned Groundwater Samples.

Type of Sample	Sample Frequency	Target Interval	Purpose	Locations
Pumped or KABIS	select intervals	Unconfined aquifer	Uranium isotope evaluation	"A," "B," "C," "D," "E," "G," "K," "L," and "M"
Pumped or KABIS	select intervals	Unconfined aquifer	Contaminant plume delineation	"A," "B," "C," "D," "E," "K," "L," "M," "N," and "O"
Pumped	select intervals	Confined aquifer	Uranium, Tc-99, and chromium evaluation	"G," and "H"
Pumped or KABIS	2.5 ft	Unconfined aquifer	Chromium and nitrate contaminant evaluation	"K" and "L"

Table 5-6. Planned Hydrologic Testing.

Type of Test	Purpose	Target Interval	Locations
Slug test	Provide initial estimates of hydraulic properties	Unconfined aquifer	"B," and "N"
Single- or multiple-well pumping test	Identify aquifer parameters for evaluation of remedial alternatives	Unconfined aquifer	"B" and "N"
Short-term well-development pumping test	Generate an estimate of aquifer transmissivity	Unconfined aquifer	"A," "B," "C," "D," "E," "I," "J," "K," "L," "M," "N," and "O"
		Confined aquifer	"F," "G," and "H"
Well tracer test	Yield a profile of hydraulic conductivity, estimate flow velocity independent of gradient measurement and stress tests	Unconfined aquifer	Selected existing wells near C Tank Farm, and selected existing wells northwest of BY Tank Farm.

KABIS sampler is a product of Sibak Industries, San Marcos, California.

Table 5-7. Planned Geophysical Investigations.

Type of Test	Purpose	Target Interval	Locations
HRR	Measure the electrical resistance of soils	Surface to groundwater	In vicinity of WMA-B/BX/BY Tank Farm and the WMA-C Tank Farm*
Borehole geophysical logging	Identify naturally occurring and gamma-emitting radionuclides	Surface to groundwater	All proposed wells

*HRR at these locations will be conducted primarily to support the WMA and source operable unit investigations.
HRR = high-resolution resistivity.
WMA = waste management area.

Table 5-8. Modeling Input Parameters. (5 Pages)

Property	Parameter	Reason for Measuring	Method
		Aquifer Sediments	
Physical/ geological	Particle size distribution (by dry sieve and wet sieve for gravel and sand, and hydrometer method for silt and clay)	Particle size influences the hydraulic properties (such as hydraulic conductivity, effective porosity, bulk density) and geochemical properties (such as cation-exchange capacity and distribution coefficient, K_d).	ASTM D421 and/or ASTM D422-63; or ASTM D6913 or ASA Method 15-5
	Calcium carbonate content (includes total carbon, inorganic carbon, and organic carbon by difference)	This parameter influences the pH buffering capacity of the sediment, which is an important for many remediation technologies using a resin based ion exchange systems. Calcium carbonate also is a cementing material in porous sediments that influences the hydraulic conductivity and porosity. Calcium carbonate content influences on the K_ds of contaminant, especially uranium Organic carbon content influences bioremediation technologies.	ASTM E1915-07a, EPA 9060A[a]
	Bulk density	Needed to calculate the retardation factor of contaminants in the transport model and porosity.	ASTM D2937-04 see precautions on sampling handling in ASTM D6640; also acceptable ASTM D4564
	Lithology	Needed to develop the geologic model used in flow and transport models for heterogeneity.	Geologist description using ASTM D2488-06; Folk, 1968; and Wentworth, 1922
Hydrological and transport	Effective porosity	Needed to calculate the water flow and the retardation factor of contaminants in the transport model.	Generally is a "fitted" parameter based on modeling calibrations and lab measurement of total porosity
	Particle Density	Needed to establish the density-volume relationship of soil/rocks. Typically used to calculate porosity and to estimate optimum moisture content in compaction tests.	Typically measured on the <2 mm fraction on 3 replicate samples using the pycnometer method ASA 1986; Method 14-3 or ASTM D854.

Table 5-8. Modeling Input Parameters. (5 Pages)

Property	Parameter	Reason for Measuring	Method
	Total porosity	Needed to calculate the water flow and the retardation factor of contaminants in the transport model.	Porosity generally is calculated by measuring bulk density of sediment in intact core and using the specific density of individual grains (generally ranges from 2.4 g/cm^3 for clays, 2.65 g/cm^3 for quartz and 2.78 g/cm^3 for coarse sand and gravels. Porosity can be measured directly (ASA 1986; Method 18-2). Use ASTM D2937-04 for measuring bulk density- and ASA Method 14-3 for particle density
	Saturated hydraulic conductivity	A measure of the ability for a soil/rock to transmit fluids when fully saturated. Needed to calculate water flow rates in each lithology.	Generally use constant head method (ASTM D2434) or use falling head method (ASA 28-4.2 or EPA Method 9100[a]); Also acceptable ASTM D5856
	Dispersivity	A measure of the amount of spreading about the center of mass because of velocity differences. Dispersivity influences retardation of COPCs through porous media	Laboratory column or field tracer measurement. See ASA 1986 Chapter 44; or Parker and van Genuchten, 1984
Geochemical	K_d (e.g., Tc-99, U(VI))	Parameter needed to calculate retardation factor for each COPC expected to dominate long-term risk	ASTM D4646-03 or PNL-3349 for inorganics
	Cation-exchange capacity or extractable cations	Often helps explain K_d values for cationic contaminants and useful for understanding sediments capacity to release competing common cations to water when performing ion exchange remediation. If COPCs are not dominated by cations the extractable cation measurement using ammonium acetate extraction is sufficient.	Routson et al., 1973 for CEC or Rhoades, 1996 for NH_4OAc
		Water	
Geochemical	Major cations (e.g., sodium, potassium, magnesium, and calcium)	Influences remediation techniques that rely on cation-exchange resins (Sr-90, Cs-137) and is useful for understanding overall geochemical conditions that control contaminant-sediment interactions.	ASTM C1111 or EPA Method 6010B[a]
	Specific conductivity	An indicator of the total dissolved ion concentration of groundwater or extracted pore water.	Field screening Version of ASTM D1125 or EPA Method 9050A[a]

Table 5-8. Modeling Input Parameters. (5 Pages)

Property	Parameter	Reason for Measuring	Method
	TOC (total dissolved organic carbon content)	Dissolved organic carbon can act as a food source during bioremdiation and some forms of dissolved organic carbon can complex cation contaminants and alter their sorption properties. Thus knowledge of the TOC helps interpret mobility [K_d] information and guide bioremediation design.	EPA Method 9060A[a] or ASTM Method D4129-88 or ASTM E1915-01 or 415.1[b]
	Alkalinity (can also be estimated from TIC measurement)	This is the key water parameter that controls pH buffering capacity and is a key complexing ligand to U(VI) and can control U(VI) sorption tendencies. Also competes with the anionic COCs for sorption onto anion exchange resins.	ASTM D1067
	pH	Key parameter for controlling acid-base buffering capacity of aquifer-sediment system. Generally influences most remediation technologies and retardation of COCs.	ASTM D1293 or EPA Method 9040C[a]
	Major anions in sediment pore water (e.g., sulfate, chloride, fluoride, nitrate, phosphate, bicarbonate/ carbonate)	Influences remediation techniques that rely on anion-exchange resins (U(VI), Tc-99) and is useful for understanding overall geochemical conditions that control contaminant-sediment interactions.	Use IC; following two methods are equivalent ASTM D4327 or EPA Method 9056[a]
	Dissolved oxygen or Eh measurement	Indicators for the redox state of the aquifer. Many COCs are redox sensitive (e.g., Tc-99, U, Cr, Se, Pu, Np). Knowing redox state aids in determining COC speciation and mobility. It helps select appropriate remediation techniques for redox sensitive COCs.	DO: Field screening Eh: lab measurement [ASTM-D 1498]; ASA 1986 Method 49-2 and 49-3
	Ferrous Iron Content	Indicator for the redox state of the aquifer. Many COCs are redox sensitive (e.g., Tc-99, U, Cr, Se, Pu, Np. Knowing redox state aids in determining COC speciation, mobility, and appropriate remediation techniques.	Ferrozine colorimetric method (Gibbs, 1976)

Table 5-8. Modeling Input Parameters. (5 Pages)

Property	Parameter	Reason for Measuring	Method
	COC concentrations	Need to know dissolved concentrations of each COC at each depth at each well sampled to develop plume distribution maps	Various techniques dependent on COC; today most RCRA metals and long lived radionuclides (e.g., U, Tc-99, I-129, Np-237, Pu-239) are measured using ICP-MS using ASTM D5673 or EPA Method 6020[a] , carbon tetrachloride(CCl_4) and its primary degradation products are measured using EPA Methods 8260B (GC/MS), or 8021B(GC-PID), or PNNL-15239
	Isotope Signature Testing	Knowledge of isotope distribution of elements such as Ru, N (i.e., nitrogen in nitrate, nitrite, and ammonium), uranium, and perhaps other mobile fission products such as molybdenum, rhodium, palladium allows one to estimate the source (from which disposal facility) of the contamination	Various techniques dependent on element. Most rely upon some pre-treatment of water to isolate the desired analyte from others and to concentrate it and then use of various mass spectroscopic techniques to accurately quantify the desired (generally stable) isotopes. See for example Dresel et al. (2002), Christensen et al. (2002), Singleton et al. (2005) and Brown et al. (2005)

[a]Method from Eaton et al., 1995, *Standard Methods for Examination of Water and Wastewater.*
[b]Method from U.S. Environmental Protection Agency's SW-846 (available online http://www.epa.gov/epaoswer/hazwaste/test/sw846.htm).

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ASTM D 4646-03, *Standard Test Method for 24-h Batch-Type Measurement of Contaminant Sorption by Soils and Sediments*

ASTM D5673-05, *Standard Test Method for Elements in Water by Inductively Coupled Plasma-Mass Spectrometry.*

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ASTM D6913-04e1, *Standard Test Methods for Particle-Size Distribution (Gradation) of Soils Using Sieve Analysis.*

ASTM D6640-01, *Standard Practice for Collection and Handling of Soils Obtained in Core Barrel Samplers for Environmental*

Table 5-8. Modeling Input Parameters. (5 Pages)

Property	Parameter	Reason for Measuring	Method

Investigation.

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Brown, et al., 2006, "Precise Ruthenium Fission Product Isotopic Analysis Using Dynamic Reaction Cell Inductively Coupled Plasma Mass Spectrometry (DRC-ICP-MS)."

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ASTM = American Society for Testing and Materials.
EPA = U.S. Environmental Protection Agency.
ICP/MS = inductively coupled plasma/mass spectrometry.

6.0 PROJECT SCHEDULE

The project schedule for the remedial investigation activities discussed in this RI/FS work plan is provided in Table 6-1. This schedule identifies the activities which have been completed and the duration of those activities to be completed. Completion of the remaining work plan activities will be subject to available funding. As work plan activities are completed, additional characterization needs may be identified, which would require amending the work plan.

Table 6-1. Project Schedule for 200-BP-5 Groundwater Operable Unit.

Activity	Duration (Months)
Remedial Field Investigations	
HRR Field Work & Report	Complete
Drilling, Sample Collection and Analyses For A Through J Wells	Complete
Drilling, Sample Collection and Analyses For K Through M Wells	12
Drilling, Sample Collection and Analyses For N And O Wells	Complete
Pumping Tests At B And N Wells	Complete
Vertical Depth Discrete Sampling	9
Remedial Investigation Report	
Prepare And Deliver Draft A To EPA	15
Feasibility Study	
Prepare And Deliver Draft A To EPA	19
Proposed Plan	
Prepare And Deliver Draft A To EPA	19

HRR = high-resolution resistivity.

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7.0 REFERENCES

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APPENDIX A

SAMPLING AND ANALYSIS PLAN FOR THE 200-BP-5 GROUNDWATER OPERABLE UNIT REMEDIAL INVESTIGATION/FEASIBILITY STUDY

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FIGURES

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TERMS

AEA	alpha energy analysis
ALARA	as low as reasonably achievable
amsl	above mean sea level
ASTM	American Society for Testing and Materials
bgs	below ground surface
CAS	Chemical Abstracts Service
CERCLA	*Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
CFR	*Code of Federal Regulations*
COC	contaminant of concern
COPC	contaminant of potential concern
DOE	U.S. Department of Energy
DQO	data quality objective
DTW	depth to groundwater
EPA	U.S. Environmental Protection Agency
FH	Fluor Hanford, Inc.
GEA	gamma energy analysis
GPC	gross proportional counting
HEIS	*Hanford Environmental Information System* database
HRR	high-resolution resistivity
K_d	distribution coefficient
MCL	maximum contaminant level
N/A	not applicable
NMLS	Neutron-Moisture Logging System
WTPH-DX	Washington total petroleum hydrocarbon diesel extended
NTU	nephelometric turbidity unit
ORIGEN2	Oak Ridge Isotope GENeration and depletion code
OU	operable unit
PNNL	Pacific Northwest National Laboratory
PUREX	Plutonium-Uranium Extraction (Plant or process) (tributyl phosphate solvent extraction)
QA	quality assurance
QAPjP	quality assurance project plan
QC	quality control
RCRA	*Resource Conservation and Recovery Act of 1976*
REDOX	Reduction-Oxidation (Plant or process) (hexone-based solvent extraction)
RESRAD	RESidual RADioactivity (dose model)
RI	remedial investigation
RI/FS	remedial investigation/feasibility study
RL	U.S. Department of Energy, Richland Operations Office
SAP	sampling and analysis plan
SGLS	Spectral Gamma Logging System
SIM	*Hanford Soil Inventory Model, Rev. 1* (RPP-26744)

STOMP	Subsurface Transport Over Multiple Phases (code)
TBD	to be determined
TD	total depth
TIC	tentatively identified compound
TOC	total organic carbon
Tri-Party Agreement	*Hanford Federal Facility Agreement and Consent Order* (Ecology et al., 1989)
WAC	*Washington Administrative Code*
WMA	waste management area
WSCF	Waste Sampling and Characterization Facility

METRIC CONVERSION CHART

Into Metric Units

If you know	*Multiply by*	*To get*
Length		
inches	25.40	millimeters
inches	2.54	centimeters
feet	0.305	meters
yards	0.914	meters
miles (statute)	1.609	kilometers
Area		
sq. inches	6.452	sq. centimeters
sq. feet	0.0929	sq. meters
sq. yards	0.836	sq. meters
sq. miles	2.591	sq. kilometers
acres	0.405	hectares
Mass (weight)		
ounces (avoir)	28.349	grams
pounds	0.454	kilograms
tons (short)	0.907	ton (metric)
Volume		
teaspoons	5	milliliters
tablespoons	15	milliliters
ounces (U.S., liquid)	29.573	milliliters
cups	0.24	liters
pints	0.473	liters
quarts (U.S., liquid)	0.946	liters
gallons (U.S., liquid)	3.785	liters
cubic feet	0.0283	cubic meters
cubic yards	0.764	cubic meters
Temperature		
Fahrenheit	(°F-32)*5/9	Centigrade
Radioactivity		
picocurie	37	millibecquerel

Out of Metric Units

If you know	*Multiply by*	*To get*
Length		
millimeters	0.0394	inches
centimeters	0.394	inches
meters	3.281	feet
meters	1.094	yards
kilometers	0.621	miles (statute)
Area		
sq. centimeters	0.155	sq. inches
sq. meters	10.764	sq. feet
sq. meters	1.196	sq. yards
sq. kilometers	0.386	sq. miles
hectares	2.471	acres
Mass (weight)		
grams	0.0353	ounces (avoir)
kilograms	2.205	pounds (avoir)
ton (metric)	1.102	tons (short)
Volume		
milliliters	0.034	ounces (U.S., liquid)
liters	2.113	pints
liters	1.057	quarts (U.S., liquid)
liters	0.264	gallons (U.S., liquid)
cubic meters	35.315	cubic feet
cubic meters	1.308	cubic yards
Temperature		
Centigrade	(°C*9/5)+32	Fahrenheit
Radioactivity		
millibecquerel	0.027	picocurie

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APPENDIX A

SAMPLING AND ANALYSIS PLAN FOR THE 200-BP-5 GROUNDWATER OPERABLE UNIT REMEDIAL INVESTIGATION/FEASIBILITY STUDY

A1.0 INTRODUCTION

This sampling and analysis plan (SAP) supports the planned 200-BP-5 Groundwater Operable Unit (OU) remedial investigation/feasibility study (RI/FS) field characterization activities. These activities are outlined in the main text of the 200-BP-5 Groundwater OU RI/FS work plan. WMP-28945, *Data Quality Objective Summary Report in Support of the 200-BP-5 Groundwater Operable Unit Remedial Investigation Feasibility Study Process*, documents the scoping process for the 200-BP-5 Groundwater OU remedial investigation (RI) characterization activities.

The scoping process (summarized in WMP-28945) identified a number of data needs to be addressed during the 200-BP-5 Groundwater OU RI/FS process. These data needs are further described in the 200-BP-5 Groundwater OU RI/FS work plan and are the basis for the RI/FS field characterization activities.

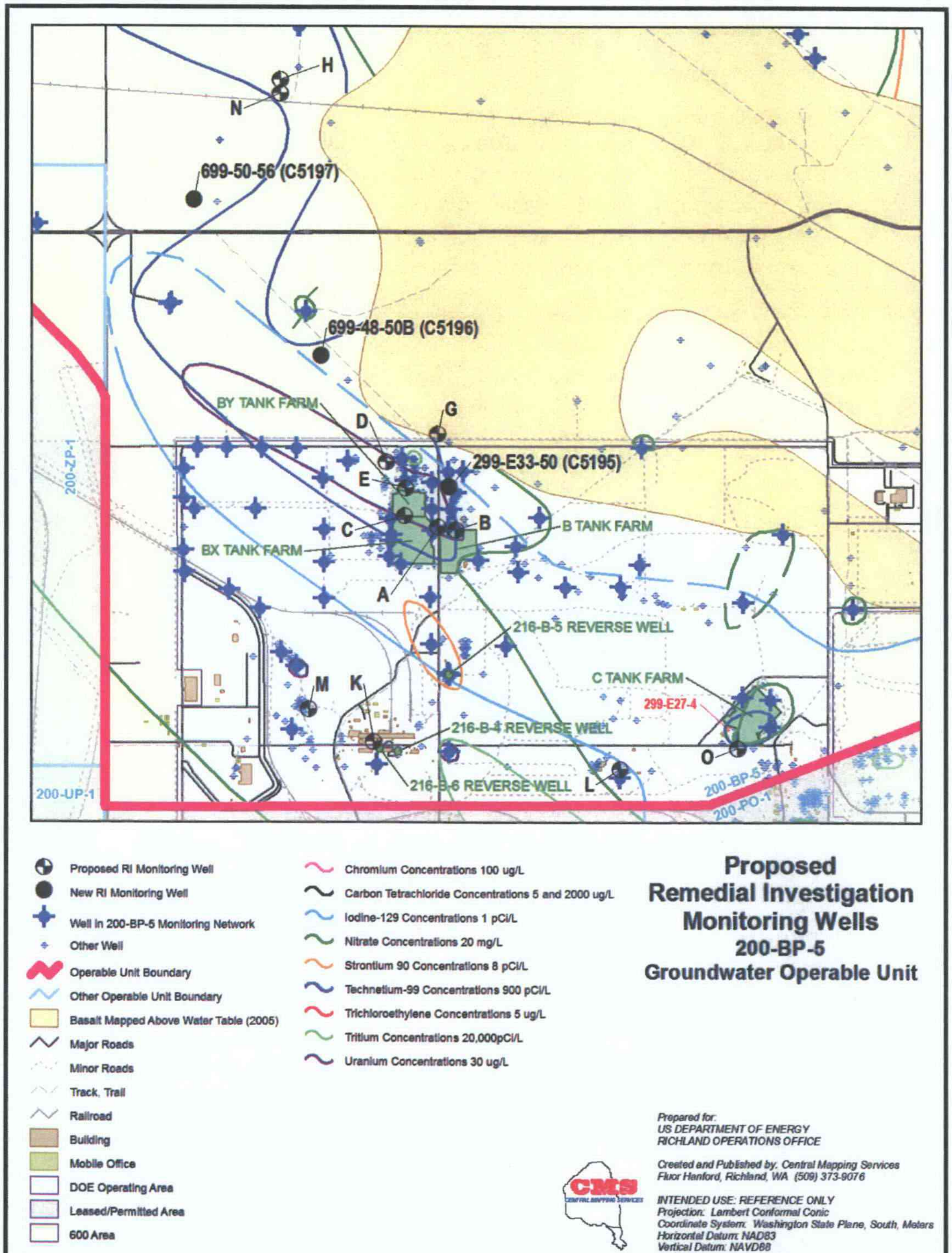
Drilling and construction of 15 groundwater-monitoring wells and associated sampling is the principal field characterization activity associated with the 200-BP-5 Groundwater OU RI/FS. The locations of the 15 proposed wells are shown in Figure A1-1. During the data quality objective (DQO) scoping process, each of the proposed wells was assigned an identification using the letters "A" through "O." Of 15 proposed wells, 8 are primarily for vadose zone and groundwater characterization ("A," "B," "C," "D," "E," "K," "L," and "M"), 3 are for characterizing and monitoring the confined aquifer ("F," "G," and "H"), and 4 are for characterizing and monitoring the unconfined aquifer ("I," "J," "N," and "O"). Data collected from the planned wells will provide the information necessary to determine if any contingency wells will be necessary.

Drilling at three of the proposed well locations, "F" (299-E33-50 [C5195]), "I" (699-48-50B [C5196]), and "J" (699-50-56 [C5197]), was initiated at the beginning of fiscal year 2007 before completion of the 200-BP-5 Groundwater OU RI/FS work plan. DOE/RL-2006-55, *Sampling and Analysis Plan for FY 2006 200-BP-5 Groundwater Operable Unit Remedial Investigation/Feasibility Study*, details the well design and sampling requirements for these three wells. This SAP primarily addresses well design and sampling requirements for the remaining 12 proposed wells ("A," "B," "C," "D," "E," "G," "H," "K," "L," "M," "N," and "O"). The well locations are preliminary and may be revised as new characterization data are collected through well drilling and sampling or from supplemental *Resource Conservation and Recovery Act of 1976* investigations ongoing at the tank farms (e.g., high-resolution resistivity [HRR]) or *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) source OU investigations.

The following is a summary of the purpose for each of the proposed 200-BP-5 Groundwater OU RI wells as presented in WMP-28945:

- New well "A" is proposed to be installed east of the BX Tank Farm, between existing wells 299-E33-41 and 299-E33-18. The purpose of this well is to provide additional information regarding local uranium contaminant inventory in the vadose zone.

Figure A1-1. Locations of Proposed Wells Associated with 200-BP-5 Groundwater Operable Unit Remedial Investigation.



O:\Projects\2006\OperableUnits\200BP5\061002_WorkPlan_Thomas\Maps\070125_SAPProposedRIWells_8-5x11_Rev4.mxd - 2/27/2008 @ 11:22:05 AM

- New well "B" is proposed to be installed to the southeast of well 299-E33-18 and west of the 216-B-7A Crib. The purpose is to provide information regarding lateral migration of contaminants from the 216-B-7A Crib vadose zone and the B Tank Farm to well 299-E33-18. This well also will confirm the top of the basalt in the area near well 299-E33-18 and provide depth-discrete groundwater samples in the aquifer to define the extent and concentration of contamination in this apparent deep aquifer anomaly. This well potentially could be used as an extraction well if pump-and-treat activity is determined to be the most feasible alternative for remediation of the growing uranium plume.
- New well "C" is proposed to be installed between the northern-most line of tanks in the BX Tank Farm and the southern-most line of tanks in the BY Tank Farm. The purpose is to provide vertical nature and extent of contamination from the assumed cascade line leak between tanks 241-BX-103 and 241-BY-101, to possibly identify lateral extent of contamination from spills/leaks associated with tanks 241-BX-106 and 241-BX-102, and to possibly identify the lateral extent of contamination from assumed leaking tank 241-BY-107. This well also will confirm the top of the basalt in this area and provide depth-discrete groundwater samples in the aquifer to define the extent and concentration of contamination in this part of the aquifer.
- New well "D" is proposed to be installed west of the BY Cribs and will provide information regarding the western extent of vadose-zone contamination from the BY Cribs and additional information of the dipping, thin-layer, low-permeability zone. This well also will confirm the top of the basalt in this area and help to identify contaminant dissipation to the west. This well potentially could be used as an extraction well if pump-and-treat activity is determined to be the most feasible alternative for remediation of the erratic technetium plume in this area.
- New well "E" is proposed to be installed south of the BY Cribs and north of the BY Tank Farm. The purpose is to provide vertical extent of moisture in the vadose zone that possibly is linked with the high chloride concentrations reported from nearby wells in this area, possibly identify perched aquifers or high moisture zones that possibly connect laterally and extend to sediments beneath the northern portion of tank 241-BY-106, and possibly monitor the migration of deep contamination from the BY Cribs. This well also will confirm the top of the basalt in this area and provide depth-discrete groundwater samples in the aquifer to define the extent and concentration of contamination in this part of the aquifer. This well potentially could be used as an extraction well if pump-and-treat activities were determined to be the most feasible alternative for remediation of the growing uranium plume.
- New wells "G" and "H" also are proposed for installation in the Rattlesnake Ridge confined aquifer. If analytical data from well "F" demonstrate no contamination, then well 299-E33-12 will be decommissioned and well "G" would be located downgradient of well 299-E33-12 to confirm proper decommissioning and to provide long-term monitoring of the upper confined aquifer. Well "H" is recommended upgradient of well 699-53-55 (south) to assess potential intercommunication between the unconfined aquifer and the confined aquifer. Well "H" also will be used to determine the top of basalt for the confined aquifer in this area, identify the depth of the confined aquifer, and

provide depth-discrete groundwater samples in the confined aquifer to define the extent of technetium contamination south of well 699-53-55.

- New well "K" is proposed for installation near the 216-B-6 Reverse Well, south of the B Plant. The purpose of this well is to determine the extent of contamination in the deep vadose zone and groundwater near this reverse well. Uncertainty exists where the depth of the screen interval for the 216-B-6 Reverse Well is located. Documents indicate the screen interval could be 75 ft below ground surface (bgs), 161 ft bgs, or 302 ft bgs. Recent Soil Inventory Model (*Hanford Soil Inventory Model, Rev. 1* [RPP-26744]) (SIM) estimates indicate that the median inventory for chromium is nearly 2,500 kg and the mobile radionuclide inventory did not exceed 1 Ci. The highest mobile radionuclide curie content according to the SIM was associated with tritium and technetium. Nitrate, chloride, and sodium concentrations also were significant (58,373 kg, 675 kg, and 26,954 kg, respectively). In addition, the only well near this location is well 299-E28-51, which terminates at 75 bgs, which is well above the groundwater.

- New well "L" is proposed for installation near the 216-C-1 Hot Semiworks Plant. The 216-C-1 Hot Semiworks Plant waste site was the source of cold-run waste and process condensate from the 201-C Process Building from 1953 to 1957. The waste inventory indicates that this site received 23,400,000 L of high-salt waste, cold-run waste, and process condensate of experimental reduction-oxidation (REDOX) and plutonium-uranium extraction (PUREX) effluent. Waste inventories for chromium, uranium, plutonium, and strontium were estimated at 57,724 kg, 300 kg, 8 g, and 85.5 Ci, respectively. The effluent to pore-space ratio was calculated at 29.8 during the operating period. The historic groundwater results from well 299-E24-8 (downgradient of the 216-C-1 Hot Semiworks Plant during active B Pond effluent discharges) only covered some of the contaminants of potential concern (COPC). The nitrate data reported in the 1960s from wells 299-E27-5 (upgradient) and 299-E24-8 (downgradient) of the 216-C-1 Hot Semiworks Plant indicate possible contributions from the 216-C-1 Hot Semiworks Plant. These historical nitrate concentrations reported in groundwater exceeded the current maximum contaminant level (MCL) for nitrate by two orders of magnitude.

- New well "M" is proposed as a replacement for well 299-E28-16 at the 216-B-12 Crib. The 216-B-12 Crib waste site had one of the largest waste inventories for uranium (21,000 kg), plutonium (374 g), and cesium (716 Ci), and the effluent to pore-space ratio was calculated at 28.4, with 520 million L of effluent disposed during the operating period of 1952 to 1973. The 200-PW-2 RI results for COCs at the 216-B-12 Crib were compared with protections of groundwater standards and the following contaminants exceeded protection standards: nitrate, tritium, and uranium. Of these contaminants, tritium was the only contaminant that was modeled to impact groundwater within the next 1,000 years. The tritium concentrations were projected to peak in approximately 526 years. The peak concentration was estimated at 6.3×10^{-10} pCi/L; however, based on the inventory, it is uncertain if the 200-PW-2 RI results at the 216-B-12 Crib are truly representative. Past annual groundwater reports have reported a mid-1980s groundwater uranium plume north of this waste site. Therefore, it is recommended that a well be placed proximal to the 216-B-12 Crib to replace well 299-E28-16 because only one groundwater well is currently located near this waste site. This well also will provide depth-discrete groundwater samples in the aquifer to define the extent of past sorbed uranium contamination if present.

- New well "N" is intended to be completed in unconsolidated sediments above the Elephant Mountain Member basalt unit, where it is eroded at the edge of a paleo-channel created by cataclysmic flood events, which created a "window" in the top basalt flow to the north. Ideally, it will intersect the technetium plume in this aquifer close to where the unconfined aquifer thickens in the channel to the north. Confined aquifer well "H" will be drilled within 10 ft of well "N." An aquifer-pumping test is planned to determine the hydraulic properties of the unconfined aquifer located above the Elephant Mountain Member basalt.
- New well "O" will be drilled in the vicinity of the C Tank Farm, exploring the unconfined aquifer in the region of a technetium plume. This activity should resolve uncertainty regarding technetium inventory from past releases that have migrated into the groundwater at the C Tank Farm.

This SAP contains the following five chapters:

- Chapter A1.0 – Summarizes the recent DQO process output and the data needs
- Chapter A2.0 – Provides the quality assurance project plan
- Chapter A3.0 – Provides the field-sampling plan
- Chapter A4.0 – Provides the health and safety plan
- Chapter A5.0 – Provides a list of the references cited.

A1.1 DATA QUALITY OBJECTIVES

Guidance from the U.S. Environmental Protection Agency (EPA) (EPA/240/B-06/001, *Guidance on Systematic Planning Using the Data Quality Objectives Process*, EPA QA/G-4) was used to support the development of this SAP. The DQO process is a strategic planning approach for defining the criteria that a data-collection design should satisfy. The DQO process is used to ensure that the type, quantity, and quality of environmental data used in decision making will be appropriate for the intended application.

This section focuses on the groundwater and vadose-zone COPCs and COCs developed during the DQO process. Additional details of the DQO process are documented in WMP-28945. A review of the 200-BP-5 Groundwater OU data needs and the development of the rationale for the planned 200-BP-5 Groundwater OU RI characterization activities are included in Chapter 4.0 of the 200-BP-5 Groundwater OU RI/FS work plan. Chapter 5.0 of the 200-BP-5 Groundwater OU RI/FS work plan includes a description of the planned 200-BP-5 Groundwater OU RI/FS characterization activities and is the basis for the activities included in this SAP.

A1.1.1 Identification of Preliminary Contaminants of Potential Concern

The vadose zone and groundwater COPCs were developed during the DQO process to guide 200-BP-5 Groundwater OU RI characterization activities. In general, these constituents will comprise the analyte lists for sediment and groundwater samples collected during the RI. A final COC list will be developed during the baseline risk assessment, following the field portion of the RI. The final COC list will consist of constituents that are determined (based on analytical data and modeling) to exceed human health and ecological risk thresholds. The vadose-zone COPCs are included in this groundwater field investigation of the RI in order to evaluate potential emerging groundwater contamination. As mentioned in the work plan, the subsequent modeling and determination of appropriate remedial alternatives will be associated with the appropriate and responsible overlying source waste site or unplanned release.

The vadose zone and groundwater preliminary COPCs were developed from a list of constituents of interest using a tiered approach that is explained in detail in WMP-28945. The list of constituents of interest represented an exhaustive list of potential or known vadose-zone contaminants overlying the 200-BP-5 Groundwater OU and groundwater contaminants within the 200-BP-5 Groundwater OU. This list is provided in WMP-28945, Table 1-4. The primary documents used to develop the list of constituents of interest included the following:

- DOE/RL-92-19, *200 East Groundwater Aggregate Area Management Study Report*
- DOE/RL-92-70, *Phase I Remedial Investigation Report for 200-BP-1 Operable Unit*
- DOE/RL-99-07, *200-CW-1 Operable Unit RI/FS Work Plan and 216-B-3 RCRA TSD Unit Sampling Plan*
- DOE/RL-99-44, *200-CS-1 Operable Unit RI/FS Work Plan and RCRA TSD Unit Sampling Plan*
- DOE/RL-2000-38, *200-TW-1 Scavenged Waste Group Operable Unit and 200-TW-2 Tank Waste Group Operable Unit RI/FS Work Plan*
- DOE/RL-2000-60, *Uranium-Rich/General Process Condensate and Process Waste Group Operable Units RI/FS Work Plan and RCRA TSD Unit Sampling Plan; Includes 200-PW-2 and 200-PW-4 Operable Units*
- DOE/RL-2001-65, *200-MW-1 Miscellaneous Waste Group Operable Unit RI/FS Work Plan*
- DOE/RL-2001-66, *Chemical Laboratory Waste Group Operable Units RI/FS Work Plan, Includes: 200-LW-1 and 200-LW-2 Operable Units.*

An extensive list of documents used to support research of potential constituents of interest and support the overall DQO scoping process is included in WMP-28945, Appendices A through D.

Hanford Site databases and a radionuclide inventory code (listed below) also were integral in researching contaminant data and inventory information from the various waste sites and groundwater monitoring wells located within the 200-BP-5 Groundwater OU.

- The *Waste Information Data System* database comprises the official summary of the history and status of Hanford waste sites.
- The *Hanford Environmental Information System* (HEIS) database contains current analytical data for soil, biota, atmospheric, miscellaneous material, surface water, and groundwater samples.
- The *Environmental Data Access* database is used to compile analytical data from HEIS into groundwater quality well summary tables for the 200-BP-5 Groundwater OU. The summary tables provide a breakdown of the number of samples, detects, date first sampled, and last sample date for various categories (e.g., radionuclides, volatiles,

semivolatiles, pesticides, metals, general chemistry [i.e., anions, cations], and physical properties).

- The *Virtual Library* provides laboratory reviewer comments and trend plots on individual analysis and various constituents, respectively.
- The *Hanford Well Information System* database consists of information regarding the locations, as-built diagrams, and maintenance records for wells and boreholes for the Hanford Site.
- The *Hanford Geographic Information System* contains detailed, accurate maps of the Hanford Site and its main features, such as buildings, roads, aboveground and underground services, structures, piping, topography, geology, wells, and rivers and ponds.
- The Oak Ridge Isotope GENeration and depletion code (ORIGEN2) contains the curie content per ton of uranium fuel for the highest inventories of actinides, fission products, and activation products, as well as the degradation of inventory over 5, 10, 25, and 50 years. The code was established for C and N Reactor production.

The next step in the development of the COPCs involved screening the list of constituents of interest using a set of exclusion criteria. For vadose-zone constituents, the primary rationale for excluding a radiological constituent of interest was due to insignificant inventory levels (from waste site inventory records), either through decay or lack of in-growth due to long parent half-life.

For nonradiological constituents of interest, the primary rationale for excluding a constituent was because it was not regulated under WAC 173-340-740, "Model Toxics Control Act -- Cleanup," "Unrestricted Land Use Soil Cleanup Standards," for protection of groundwater or the sample data from previous investigations indicate that the constituent does not pose a current or future threat to the groundwater. For instance, several of the semivolatile organic constituents of interest were listed as a result of known surface pesticide applications. The associated pesticide constituents were evaluated and determined not to be a threat to the deep vadose zone. A detailed review of the constituents excluded during the screening process and an explanation of the exclusion rationale are included in WMP-28945, Table 1-5.

The primary exclusion criteria for evaluating the groundwater constituents of interest are listed below. A detailed review and explanation of the rationale for constituent exclusion or listing of a constituent as a COPC is included in WMP-28945, Appendix F. This screening process included a review of groundwater data during the period 1987 to present from 100 selected wells.

- For all constituents (i.e., radiological and nonradiological), if analytical concentrations were below laboratory detection limits (i.e., all nondetects), then the constituent was excluded.
- For nonradiological constituents, if the maximum reported value for a constituent was less than the Hanford Site background concentration (DOE/RL-92-24, *Hanford Site Background: Part 1, Soil Background for Nonradioactive Analytes*; DOE/RL-96-61, *Hanford Site Background: Part 3, Groundwater Background*), then the constituent was excluded.

- For nonradiological constituents, if the maximum value for a constituent was less than the EPA's primary or secondary drinking water standards and/or groundwater cleanup levels established according to WAC 173-340-720(4), "Ground Water Cleanup Standards," "Method B Cleanup Levels for Potable Ground Water," then the constituent was excluded.
- For radionuclides, if the maximum value determined by analysis or ORIGEN2 modeling was less than EPA's recommended 4 mrem/yr ingestion dose limit (for beta and photon emitters) or less than 15 pCi/L for alpha emitters, then the constituent was excluded.
- All radionuclide decay series were evaluated to determine key radionuclide indicators for radionuclide contaminants with no sample results or limited sample results. The key radionuclides were used for comparison from ORIGEN2 inventory calculations. Generally, the radionuclides that were excluded were found to have insignificant ORIGEN2 inventories and were daughter products with low potential of in-growth in the next 1,000 years or more. Note that none of the excluded radionuclides have been determined (e.g., through draft source waste site RI/FS reports) to impact groundwater now or in the future.

The criteria for retaining constituents as a COPC followed the logic below. This rationale applies to constituents that have exceeded regulatory requirements in the past.

- For radiological and nonradiological constituents currently exceeding regulatory requirements (e.g., EPA's primary or secondary drinking water standards and/or groundwater cleanup levels established according to WAC 173-340-720(4), then the contaminants were retained as COPC.
- For radiological and nonradiological constituents exceeding regulatory requirements in the past, however, not exceeding regulatory requirements for the past 3 years or not having been sampled for over 5 years, then the constituent was retained as a COPC.

The additional exclusion rationale for constituents not meeting the above definitions is as follows.

- If the reported concentrations exceeded regulatory requirements in the past, however, the reported values exceeding regulatory requirements are not consistent with duplicate values and no other results were above regulatory requirements, then the constituent was excluded. (Note that this was the case for beryllium, mercury, and nickel.)
- If the reported concentrations exceeded regulatory requirements in the past, however, the wells reported with exceeding values have decreased below one-half the regulatory requirement in all wells, then the constituent was excluded. (Note that this was the case for lead.)
- If the reported concentrations exceeded regulatory requirements in the past, however, only a few results were reported above regulatory requirements, and the results were not consistent with other results from the same well, then it was excluded. (Note that this was the case for fluoride, manganese, and selenium.)
- Metal constituents required further evaluation. Unfiltered samples were observed to have significantly higher concentrations for certain metals due to particle suspension in the water. Filtered results generally were used for comparison with regulatory standards and

background concentrations. Thus, if the filtered results for a metal constituent were below regulatory standards or background concentrations, then the constituent was excluded.

A1.1.2 Final List of Contaminants of Potential Concern for the Vadose Zone

Table A1-1 presents the final list of COPCs that will comprise the analyte list for most vadose-zone samples collected during the 200-BP-5 Groundwater OU characterization activities. Because this is a comprehensive list, the analysis of some of these constituents will not be required, depending on proximity to waste sites and depth of investigation. For example, vadose-zone samples collected during drilling of proposed wells "D" and "G" will not be analyzed for volatile organic analytes and semivolatile organic analytes because these constituents are not associated with nearby BY Cribs. Additionally, no vadose-zone COPCs are targeted for analysis at proposed well sites "H" and "N" because they are located at a significant distance from any waste sources.

Table A1-1. Contaminants of Potential Concern for the Vadose Zone.

Radionuclide COPCs			
Am-241 Sb-125 C-14 Cs-137 Co-60 Eu-152	Eu-154 Eu-155 I-129 Np-237 Ni-63 Pu-238	Pu-239 Pu-240 Sr-90 Tc-99 Th-232 Th-234	H-3 (tritium) U-233 U-234 U-235 U-236 U-238
Metal COPCs			
Aluminum Antimony Arsenic Barium Beryllium Boron	Cadmium Chromium (total) Chromium (VI) Cobalt Copper Iron	Lead Lithium Manganese Mercury Nickel Selenium	Silver Strontium Thallium Uranium (total) Vanadium Zinc
Non-Metal COPCs			
Chloride Cyanide	Fluoride Nitrate	Nitrite	Sulfate
Volatile Organic Analyte COPCs			
Acetone Benzene 1-Butanol (butyl alcohol) 2-Butanone (MEK) Carbon tetrachloride Chlorobenzene Chloroform	cis-1,2-Dichloroethene Dichloromethane (methylene chloride) 1,1-Dichloroethane 1,2-Dichloroethane Diethyl ether Ethylbenzene	Ethylene glycol Halogenated hydrocarbons 4-Methyl-2-pentanone (MIBK) Styrene Toluene	trans-1,2-Dichloroethene 1,1,1-Trichloroethane 1,1,2-Trichloroethane Trichloroethene Trichlorofluoromethane Tetrachloroethene Xylene
Semivolatile Organic Analyte COPCs			
3-Methylphenol 4-Methylphenol Bis(2-ethylhexyl)phthalate	Naphthalene Phenol	Pentachlorophenol Pyrene	Total petroleum hydrocarbons – as kerosene

COPC = contaminant of potential concern.

A1.1.3 Contaminants of Potential Concern Determined by Calculation for the Vadose Zone

Table A1-2 lists all of the vadose-zone contaminants that are to be determined by calculation. These COPCs have no readily available analysis method and, therefore, will be determined through the ORIGEN2 model. The rationale for each COPC is provided in Table A1-2.

Table A1-2. Contaminants of Potential Concern to be Determined by Calculation for the Vadose Zone.

COPCs	Rationale for Determination by Calculation
Radionuclides	
Ba-137m	Ba-137m is a meta-stable isotope produced by the beta emission from Cs-137. The decay of this isotope is factored into the Cs-137 regulatory action limit. Can be calculated based on ORIGEN2 modeling.
Am-242 and Am-242m	By association with Pu-238. Americium-242 and Am-242m are associated with the Am-242m decay series. The decay series starts with Am-242m decaying by alpha emission to Np-238, which loses a beta particle, being reduced to Pu-238. According to ORIGEN2, the inventory values of Am-242 and Am-242m are 2.5 orders of magnitude less inventory than Pu-238, 10 and 50 years after discharge. Because plutonium and americium have not shown to be mobile in the representative waste sites studied overlying the 200-BP-5 Groundwater OU, these constituents only will be considered in the deep vadose zone for the 216-B-5 and 216-B-6 Reverse Wells, which were completed in the deep vadose zone.
Am-243, Cm-244, Cm-245, Np-239, and Pu-241	Constituents with atomic mass number greater than or equal to 242 represent <1% of the actinide activity (based on ORIGEN2 modeling of Hanford Site reactor production). Because these heavy isotopes are not considered mobile in the representative waste sites studied overlying the 200-BP-5 Groundwater OU, these constituents only will be considered in the deep vadose zone for the 216-B-5 and 216-B-6 Reverse Wells, which were completed in the deep vadose zone.
Sm-151	Samarium-151 is an isobaric fission product associated with short-lived fission decay chains; however, Sm-151 has a half-life of 90 years; therefore, it is determined by calculation. Based on ORIGEN2, the concentrations of Sm-151 should be approximately 2 orders of magnitude less than Cs-137 concentrations after 50 years.
Th-231	Thorium-231 is associated with the U-235 decay chain. Can be calculated from ORIGEN2 modeling for U-235 data.
Pa-231, Pa-234, and Pa-234m	Uranium daughter; considered in uranium dose/risk estimates. Can be calculated based on ORIGEN2 modeling.
U-236	Uranium-236 is part of the Cm-244 and Cm-248 decay chain. Can be calculated from ORIGEN2 modeling for Pu-240 data.
Y-90	Yttrium-90 is a daughter product of Sr-90. Based on a short half-life it is in secular equilibrium with Sr-90. Will be associated with Sr-90 until Sr-90 decays to insignificant concentrations. Can be calculated from ORIGEN2 modeling.

COPC = contaminant of potential concern.
ORIGEN2 = Oak Ridge Isotope GENeration and depletion code.
OU = operable unit.

A1.1.4 List of Contaminants of Potential Concern for the Saturated Zone

Table A1-3 presents the list of COPCs that either were reported in the past exceeding regulatory requirements and have not been analyzed recently or never were analyzed and based on ORIGEN2 results may have high activation products. Table A1-5 in Section A1.1.5 provides the COPCs that will be calculated based on association with analyzed COPCs. Note that many of these constituents (e.g., Am-241, Ba-137m, Np-237, Pu-238, Pa-234m, Th-231, Th-234, and cadmium) did not exceed calculated regulatory limits but were retained for precautionary reasons. In addition, many anions and cations are being analyzed for geochemical reasons (e.g., ion balance). With this approach, if any constituents not making this initial list are found to be required through the data quality assessment process then the constituent will be included for the baseline risk assessment.

Table A1-3. Contaminants of Potential Concern for the Saturated Zone.

Radionuclide COPCs			
Am-241[a] C-14 Co-60	Np-237 Pu-238 Th-232[a]	Th-234[a] U-233 U-234	U-235 U-238
Metal COPCs			
Aluminum Antimony[c] Arsenic[d]	Cadmium[b] Chromium[b]	Chromium (hexavalent)[b] Iron[b,c]	Sodium[b] Thallium
Non-Metal COPCs			
Chloride[b]	Nitrite[b]		
Volatile Organic Analyte COPCs			
Chloroform	Methylene chloride		
Semivolatile Organic Analyte COPCs			
Bis(2-ethylhexyl)phthalate	Pentachlorophenol		

[a]216-B-5 Reverse Well only.
[b]Waste Management Area B/BX/BY.
[c]218-E-10 and 218-E-12 Burial Grounds.
[d]216-B-63 Trench.

COPC = contaminant of potential concern.

Table A1-4 presents the list of COPCs that were reported recently at levels exceeding groundwater drinking standard requirements.

These lists of analytes are required for saturated zone sediment samples and groundwater samples collected during the 200-BP-5 Groundwater OU RI characterization activities. Additional parameters that will be monitored include indicators of contamination such as pH (MCL = >8.5 or <4), gross alpha (MCL = 15 pCi/L), and gross beta (MCL = 50 pCi/L).

Table A1-4. Contaminants of Potential Concern for the Saturated Zone.

Radiological			
Cs-137 [a] I-129	Pu-239[a] Pu-240[a]	Sr-90 [a] Tc-99 [b,d]	H-3 (tritium) [b,c] Uranium (total) [b]
Nonradiological			
Cyanide [b,d]	Nitrate	Sulfate [b,c]	

[a]216-B-5 Reverse Well only.
[b]Waste Management Area B/BX/BY.
[c]218-E-10 and 218-E-12 Burial Grounds.
[d]Waste Management Area C.

A1.1.5 Contaminants of Potential Concern to be Determined by Calculation for Saturated Zone

Table A1-5 lists all of the saturated sediment and groundwater contaminants that are to be determined by calculation and the basis for the calculation.

Table A1-5. Contaminants of Potential Concern to be Determined by Calculation for the Saturated Zone.

Contaminant of Potential Concern	Rationale for Determination by Calculation
Radionuclides	
Ba-137m	Calculation based on Cs-137 concentrations
Pu-241	Calculation based on Am-241 concentrations
Pa-234m	Calculation based on U-238 concentrations
Th-231	Calculation based on U-235 concentrations
Y-90	Calculation based on Sr-90 concentrations

A1.1.6 Analytical Requirements

Tables A1-6 through A1-11 represent the performance requirements applicable to analysis of sediment and groundwater samples collected during the 200-BP-5 Groundwater OU RI. These requirements pertain to analysis of radiological and nonradiological constituents identified as COPCs in Tables A1-1 through A1-4. These requirements are applicable to all laboratory analyses performed on split-spoon samples, grab samples, and groundwater samples.

Table A1-12 presents the analytical performance requirements for physical, hydrologic, and geochemical measurements obtained from vadose zone and saturated zone sediment samples, aquifer testing, and borehole geophysical logging. This information will improve the site-specific information needed for predictive modeling of contaminant transport and will support the baseline risk assessment and identification and selection of groundwater remediation alternatives for the 200-BP-5 Groundwater OU.

The performance requirements included in Table A1-12 are separated into the following three categories:

- Physical properties (e.g., particle-size determination and calcium carbonate content)
- Hydraulic and transport properties (e.g., bulk density, hydraulic conductivity and total porosity)
- Model development parameters (e.g., geochemical properties, cation-exchange capacity, and distribution coefficient).

Table A1-6. Vadose Zone Analytical Performance Requirements for Radiological Constituents. (2 Pages)

COC	CAS #	Background[a] (pCi/g)	Preliminary Soil Action Level[b] (pCi/g)	Name/Analytical Technology	Target-Required Quantitation Limits Soil – Other Low Activity (pCi/g)[c]	Precision Soil[d]	Accuracy Soil[d]
Radionuclides							
Am-241	14596-10-2	N/A	TBD	Amercium-241 – AEA	1	±35%	70-130%
Sb-125	14234-35-6	N/A	TBD	GEA	1	±35%	70-130%
Cs-137	10045-97-3	1.05	TBD	GEA	0.1	±35%	70-130%
Co-60	10198-40-0	0.00842	TBD	GEA	0.05	±35%	70-130%
Eu-152	14683-23-9	N/A	TBD	GEA	0.1	±35%	70-130%
Eu-154	15585-10-1	0.0334	TBD	GEA	0.1	±35%	70-130%
E-155	14391-16-3	0.0539	TBD	GEA	0.1	±35%	70-130%
C-14	14762-75-5	N/A	291	Carbon-14 – liquid scintillation	5	±35%	70-130%
I-129	15046-84-1	N/A	TBD	Iodine-129 – liquid scintillation	2	±35%	70-130%
Ni-63	13981-37-8	N/A	TBD	Nickel-63 – liquid scintillation	30	±35%	70-130%
Np-237	13994-20-2	N/A	TBD	Neptunium-237 – AEA	1	±35%	70-130%
Pu-238	13981-16-3	0.00378	TBD	Isotopic plutonium – AEA	1	±35%	70-130%
Pu-239/240	Pu-239/240	0.0248	TBD	Isotopic plutonium – AEA	1	±35%	70-130%
Sr-89/90	RAD-SR	0.178	TBD	Total beta radiostrontium – GPC	1	±35%	65-135%
Tc-99	14133-76-7	N/A	TBD	Technetium-99 – liquid scintillation or GPC	1	±35%	65-135%
Th-232	Th-232	1.32	TBD	Isotopic thorium – AEA	1	±35%	65-135%
Th-234	Th-234	N/A	TBD	Isotopic thorium – AEA	1	±35%	65-135%
U-233/234	U-233/234	1.10	TBD	Isotopic uranium – AEA	1	±35%	65-135%
U-235/236	15117-96-1	0.109	TBD	Isotopic uranium – AEA	1	±35%	65-135%
U-238	U-238	1.06	TBD	Isotopic uranium – AEA	1	±35%	65-135%
Tritium	10028-17-8	N/A	TBD	Tritium – liquid scintillation	30	±35%	65-135%

Table A1-6. Vadose Zone Analytical Performance Requirements for Radiological Constituents. (2 Pages)

COC	CAS #	Background[a] (pCi/g)	Preliminary Soil Action Level[b] (pCi/g)	Name/Analytical Technology	Target-Required Quantitation Limits	Precision Soil[d]	Accuracy Soil[d]
					Soil – Other Low Activity (pCi/g)[c]		

NOTE: Different methods are run for different laboratories.

[a]Background levels provided by DOE/RL-96-12, *Hanford Site Background: Part 2, Soil Background for Radionuclides.*

[b]Groundwater protection radionuclide values from WDOH/320-015, *Hanford Guidance for Radiological Cleanup.* Radiological values are calculated using either the RESidual RADioactivity (RESRAD) dose model or Subsurface Transport Over Multiple Phases (STOMP) modeling of drinking water exposure with the entire vadose zone presumed to be contaminated.

[c]Target-required quantitation limits are based on contract-required detection levels.

[d]Accuracy criteria is the minimum for associated batch laboratory control sample percent recoveries. Laboratories must meet statistically based control if more stringent. Additional analyte-specific evaluations also performed for matrix spikes, and surrogates, as appropriate to the method. Precision criteria for batch laboratory replicate matrix spike analyses.

AEA = alpha energy analysis.
CAS = Chemical Abstracts Service.
COC = contaminant of concern.
GEA = gamma energy analysis.
GPC = gas proportional counting.
N/A = not applicable.
TBD = to be determined.

Table A1-7. Vadose Zone Analytical Performance Requirements for Nonradiological Chemical Constituents. (5 Pages)

COPC	CAS #	Preliminary Action Level			Name/Analytical Technology[c]	Target-Required Quantitation Limits[d]	Precision Soil[e]	Accuracy Soil[e]
		Target Method B[a] (mg/kg)	Analytical Detection Limits (mg/kg)	Background[b] (mg/kg)		Soil – Other Low Conc. (mg/kg)		
Metals								
Aluminum	7429-90-5	45.2	5	13,000	EPA Method 6010 EPA Method 200.8	5	±30%	70-130%
Antimony	7440-36-0	5.4	0.6	5	EPA Method 6010 EPA Method 200.8	0.6	±30%	70-130%
Arsenic	7440-38-2	20	1	6.47	EPA Method 6010 EPA Method 200.8	1	±30%	70-130%
Barium	7440-39-3	16,500	0.5	132	EPA Method 6010 EPA Method 200.8	0.5	±30%	70-130%
Beryllium	7440-41-7	63.2	0.2	1.51	EPA Method 6010 EPA Method 200.8	0.2	±30%	70-130%
Boron	7440-42-8	210	0.2	N/A	EPA Method 6010 EPA Method 200.8	0.2	±30%	70-130%
Cadmium	7440-43-9	0.69	0.2	N/A	EPA Method 6010 EPA Method 200.8	0.2	±30%	70-130%
Chromium	7440-47-3	2,000	0.2	0.60	EPA Method 6010 EPA Method 200.8	0.2	±30%	70-130%
Chromium (hexavalent)	18540-29-9	18.4	0.5	N/A	Chromium (hexavalent) – EPA Method 7196	0.5	±30%	70-130%
Cobalt	7440-48-4	290	2	16.9	EPA Method 6010 EPA Method 200.8	2	±30%	70-130%
Copper	7440-50-8	263	1	22	EPA Method 6010 EPA Method 200.8	1	±30%	70-130%
Iron	7439-89-6	152	5	35,000	EPA Method 6010 EPA Method 200.8	5	±30%	70-130%
Lead	7439-92-1	270	0.5	10.2	EPA Method 6010 EPA Method 200.8	0.5	±30%	70-130%

Table A1-7. Vadose Zone Analytical Performance Requirements for Nonradiological Chemical Constituents. (5 Pages)

COPC	CAS #	Preliminary Action Level			Name/Analytical Technology[c]	Target-Required Quantitation Limits[d]	Precision Soil[e]	Accuracy Soil[e]
		Target Method B[a] (mg/kg)	Analytical Detection Limits (mg/kg)	Background[b] (mg/kg)		Soil – Other Low Conc. (mg/kg)		
Lithium	7439-93-2	1,930	2.5	35	EPA Method 6010 EPA Method 200.8	2.5	±30%	70-130%
Manganese	7439-96-5	65.3	5	512	EPA Method 6010 EPA Method 200.8	5	±30%	70-130%
Mercury	7439-97-6	2.09	0.2	0.33	EPA Method 200.8 EPA Method 7471	0.2	±30%	70-130%
Nickel	7440-02-0	130	4	19.1	EPA Method 6010 EPA Method 200.8	4	±30%	70-130%
Selenium	7782-49-2	5.2	1	0.78	EPA Method 6010 EPA Method 200.8	1	±30%	70-130%
Silver	7440-22-4	13.6	0.2	0.73	EPA Method 6010 EPA Method 200.8	0.2	±30%	70-130%
Strontium	7440-24-6	2,920	1	N/A	EPA Method 6010 EPA Method 200.8	1	±30%	70-130%
Thallium	7440-28-0	1.59	0.5	N/A	EPA Method 6010 EPA Method 200.8	0.5	±30%	70-130%
Uranium (total)	7440-61-1	1.32	1	N/A	EPA Method 200.8 Uranium – kinetic phosphorescence absorption	1	±30%	70-130%
Vanadium	7440-62-2	2,240	2.5	85.1	EPA Method 6010 EPA Method 200.8	2.5	±30%	70-130%
Zinc	7440-66-6	5,970	1	67.8	EPA Method 6010 EPA Method 200.8	1	±30%	70-130%

Table A1-7. Vadose Zone Analytical Performance Requirements for Nonradiological Chemical Constituents. (5 Pages)

COPC	CAS #	Preliminary Action Level			Name/Analytical Technology[c]	Target-Required Quantitation Limits[d]	Precision Soil[e]	Accuracy Soil[e]
		Target Method B[a] (mg/kg)	Analytical Detection Limits (mg/kg)	Background[b] (mg/kg)		Soil – Other Low Conc. (mg/kg)		
Inorganics								
Chloride	16887-00-6	1,000	2	100	EPA Method 300.0	2	±30%	70-130%
Cyanide	57-12-5	0.8	0.5	N/A	EPA Method 335.2 EPA Method 9010 EPA Method 9012	0.5	±30%	70-130%
Fluoride	16984-48-8	24.1	2	2.81	EPA Method 300.0	2	±30%	70-130%
Nitrate	14797-55-8	40	2.5	52	EPA Method 300.0	2.5	±30%	70-130%
Nitrite	14797-65-0	4	2.5	N/A	EPA Method 300.0	2.5	±30%	70-130%
Sulfate	14808-79-8	1,030	5	237	EPA Method 300.0	5	±30%	70-130%
Nitrogen in nitrate and nitrite	NO2+NO3-N	4	0.75	N/A	EPA Method 335.2	0.75	±30%	70-130%
Volatile Organics								
1,1,1-trichloroethane	71-55-6	1.58	0.005	N/A	EPA Method 8260	0.005	±30%	50-150%
1,1,2-trichloroethane	79-00-5	0.00427	0.005	N/A	EPA Method 8260	0.005	±30%	50-150%
1-butanol	71-36-3	6.62	5	N/A	EPA Method 8015-M	5	±30%	50-150%
1,1-dichloroethane	75-34-3	4.37	0.010	N/A	EPA Method 8260	0.010	±30%	50-150%
1,2-dichloroethane	107-06-2	0.00232	0.005	N/A	EPA Method 8260	0.005	±30%	50-150%
2-butanone (MEK)	78-93-3	19.6	0.010	N/A	EPA Method 8260	0.010	±30%	50-150%
4-methyl-2-pentanone	108-10-1	2.71	0.010	N/A	EPA Method 8260	0.010	±30%	50-150%
Acetone	67-64-1	28.9	0.020	N/A	EPA Method 8260	0.020	±30%	50-150%
Benzene	71-43-2	0.00448	0.005	N/A	EPA Method 8260	0.005	±30%	50-150%
Carbon tetrachloride	56-23-5	0.0031	0.005	N/A	EPA Method 8260	0.005	±30%	50-150%
Chlorobenzene	108-90-7	0.874	0.005	N/A	EPA Method 8260	0.005	±30%	50-150%
Chloroform	67-66-3	0.0381	0.005	N/A	EPA Method 8260	0.005	±30%	50-150%
Cis-1,2-dichloroethene	156-59-2	0.35	0.005	N/A	EPA Method 8260	0.005	±30%	50-150%

Table A1-7. Vadose Zone Analytical Performance Requirements for Nonradiological Chemical Constituents. (5 Pages)

COPC	CAS #	Preliminary Action Level			Name/Analytical Technology[c]	Target-Required Quantitation Limits[d]	Precision Soil[e]	Accuracy Soil[e]
		Target Method B[a] (mg/kg)	Analytical Detection Limits (mg/kg)	Background[b] (mg/kg)		Soil – Other Low Conc. (mg/kg)		
Diethyl ether	60-29-7	6.68	5	N/A	EPA Method 8015-M	5	±30%	50-150%
Ethylbenzene	100-41-4	6.05	0.005	NA	EPA Method 8260	0.005	±30%	50-150%
Ethylene glycol	107-21-1	129	5	N/A	EPA Method 8015-M	5	±30%	50-150%
Methylene chloride	75-09-2	0.0218	0.005	N/A	EPA Method 8260	0.005	±30%	50-150%
Styrene	100-42-5	0.0328	0.005	N/A	EPA Method 8260	0.005	±30%	50-150%
Toluene	108-88-3	4.65	0.005	N/A	EPA Method 8260	0.005	±30%	50-150%
Trans-1,2-dichloroethene	156-60-5	0.720	0.005	N/A	EPA Method 8260	0.005	±30%	50-150%
Trichloroethene	79-01-6	0.000721	0.005	N/A	EPA Method 8260	0.005	±30%	50-150%
Trichlorofluoromethane	75-69-4	28.4	0.010	N/A	EPA Method 8260	0.010	±30%	50-150%
Tetrachloroethene	127-18-4	0.000859	0.005	N/A	EPA Method 8260	0.005	±30%	50-150%
Xylene	1330-20-7	14.6	0.010	N/A	EPA Method 8260	0.010	±30%	50-150%
Semivolatile Organics								
Bis(2-ethylhexyl)phthalate	117-81-7	13.9	0.330	N/A	EPA Method 8270	0.330	±30%	50-150%
Kerosene	108-94-1	2,000	0.330	N/A	EPA Method 8270	0.330	±30%	50-150%
Naphthalene	91-20-3	4.46	0.330	N/A	EPA Method 8270	0.330	±30%	50-150%
Phenol	108-95-2	22	0.330	N/A	EPA Method 8270	0.330	±30%	50-150%
Pentachlorophenol	87-86-5	0.0115	0.330	N/A	EPA Method 8270	0.330	±30%	50-150%
Pyrene	129-00-0	655	0.330	N/A	EPA Method 8270	0.330	±30%	50-150%
Diesel and kerosene range organics	TPH DIESEL/ TPH KEROSENE	2,000	5	N/A	NWTPH-Dx (extended to kerosene range)	5	±30%	50-150%

Table A1-7. Vadose Zone Analytical Performance Requirements for Nonradiological Chemical Constituents. (5 Pages)

COPC	CAS #	Preliminary Action Level			Name/Analytical Technology[c]	Target-Required Quantitation Limits[d]	Precision Soil[e]	Accuracy Soil[e]
		Target Method B[a] (mg/kg)	Analytical Detection Limits (mg/kg)	Background[b] (mg/kg)		Soil – Other Low Conc. (mg/kg)		

NOTE: Different methods are run for different laboratories.

[a]WAC 173-340-740(3), "Unrestricted Land Use Soil Cleanup Standards," "Method B Soil Cleanup Levels for Unrestricted Land Use," soil cleanup levels. This is the protection of groundwater concentrations determined by the three-phase partitioning model.

[b]Soil background concentration provided by either DOE/RL-92-24, *Hanford Site Background: Part 1, Soil Background for Nonradioactive Analytes*), or Ecology 94-115, *Natural Background Soil Metals Concentrations in Washington State.*

[c]For EPA Method 200.8, see EPA/600/R-94/111, *Methods for the Determination of Metals in Environmental Samples, Supplement 1.* For EPA Methods 335.2 and 300.0, see EPA/600/4-79/020, *Methods of Chemical Analysis of Water and Wastes.* For four-digit EPA methods, see SW-846, *Test Methods for Evaluating Solid Waste: Physical/Chemical Methods, Third Edition; Final Update IV-B.*

[d]Target-required quantitation limits are based on analytical detection limits. This generally is below the target Method B limits; however, in some cases the detection level is above the target Method B levels and, thus, the preliminary action level is adjusted to the detection level or background.

[e]Accuracy criteria for inorganic analyses for associated batch matrix spike recoveries. Evaluation based on statistical control of laboratory control samples also performed. Precision criteria for batch laboratory replicate matrix spike sample analyses or replicate sample analyses. Accuracy criteria for organic analyses for associated batch laboratory control sample recoveries. Laboratories must meet statistically based control if more stringent. Additional analyte-specific evaluations also performed for matrix spikes, and surrogates, as appropriate to the method. Precision criteria for batch laboratory replicate matrix spike analyses.

CAS = Chemical Abstracts Service.
COPC = contaminant of potential concern.
EPA = U.S. Environmental Protection Agency.
N/A = not applicable.
NWTPH-Dx = Northwest total petroleum hydrocarbon-diesel extended.
TPH = total petroleum hydrocarbon.
WAC = *Washington Administrative Code.*

Table A1-8. Saturated Sediment Analytical Performance Requirements for Radiological Constituents. (2 Pages)

COPC	CAS #	Background[a]	Preliminary Soil Action Level[b] (pCi/g)	Name/Analytical Technology	Target-Required Quantitation Limits	Precision Soil	Accuracy Soil
					Soil – Other Low Activity (pCi/g)[c]		
Radionuclides							
Am-241	14596-10-2	N/A	TBD	Amercium-241 – AEA	1	±35%	70-130%
Cs-137	10045-97-3	1.05	TBD	GEA	0.1	±35%	70-130%
Co-60	10198-40-0	0.00842	TBD	GEA	0.05	±35%	70-130%
C-14	14762-75-5	N/A	291	Carbon-14 – liquid scintillation	5	±35%	70-130%
I-129	15046-84-1	N/A	TBD	Iodine-129 – liquid scintillation	2	±35%	70-130%
Np-237	13994-20-2	N/A	TBD	Neptunium-237 – AEA	1	±35%	70-130%
Pu-238	13981-16-3	0.00378	TBD	Isotopic plutonium – AEA	1	±35%	70-130%
Pu-239/240	Pu-239/240	0.0248	TBD	Isotopic plutonium – AEA	1	±35%	70-130%
Sr-89/90	RAD-SR	0.178	TBD	Total beta radiostrontium – GPC	1	±35%	65-135%
Tc-99	14133-76-7	N/A	TBD	Technetium-99 – liquid scintillation or GPC	1	±35%	65-135%
Th-232	Th-232	1.32	TBD	Isotopic thorium – AEA	1	±35%	65-135%
Th-234	Th-234	N/A	TBD	Isotopic thorium – AEA	1	±35%	65-135%
U-233/234	U-233/234	1.10	TBD	Isotopic uranium – AEA	1	±35%	65-135%
U-235	15117-96-1	0.109	TBD	Isotopic uranium – AEA	1	±35%	65-135%
U-238	U-238	1.06	TBD	Isotopic uranium – AEA	1	±35%	65-135%
Tritium	10028-17-8	N/A	TBD	Tritium – liquid scintillation	30	±35%	65-135%

Table A1-8. Saturated Sediment Analytical Performance Requirements for Radiological Constituents. (2 Pages)

COPC	CAS #	Background[a]	Preliminary Soil Action Level[b] (pCi/g)	Name/Analytical Technology	Target-Required Quantitation Limits	Precision Soil	Accuracy Soil
					Soil – Other Low Activity (pCi/g)[c]		

NOTE: Different methods are run for different laboratories.

[a]Background levels provided by DOE/RL-96-12, *Hanford Site Background: Part 2, Soil Background for Radionuclides.*

[b]Groundwater protection radionuclide values from WDOH/320-015, *Hanford Guidance for Radiological Cleanup.* Radiological values are calculated using either the RESidual RADioactivity (RESRAD) dose model or Subsurface Transport Over Multiple Phases (STOMP) modeling of drinking water exposure with the entire vadose zone presumed to be contaminated.

[c]Target-required quantitation limits are based on contract required detection levels.

AEA = alpha energy analysis.
CAS = Chemical Abstracts Service.
COPC = contaminant of potential concern.
GEA = gamma energy analysis.
GPC = gas proportional counting.
N/A = not applicable.
TBD = to be determined.

Table A1-9. Saturated Sediment Analytical Performance Requirements for Nonradiological Chemical Constituents. (3 Pages)

COPC	CAS #	Preliminary Action Level			Name/Analytical Technology[c]	Target-Required Quantitation Limits[d]	Precision Soil[e]	Accuracy Soil[e]
		Target Method B[a] (mg/kg)	Analytical Detection Limits (mg/kg)	Background[b] (mg/kg)		Soil – Other Low Conc. (mg/kg)		
Metals								
Aluminum	7429-90-5	45.2	5	13,000	EPA Method 6010 EPA Method 200.8	5	±30%	70-130%
Antimony	7440-36-0	5.4	0.6	5	EPA Method 6010 EPA Method 200.8	0.6	±30%	70-130%
Arsenic	7440-38-2	20	1	6.47	EPA Method 6010 EPA Method 200.8	1	±30%	70-130%
Cadmium	7440-43-9	0.69	0.2	N/A	EPA Method 6010 EPA Method 200.8	0.2	±30%	70-130%
Chromium	7440-47-3	2,000	0.2	0.60	EPA Method 6010 EPA Method 200.8	0.2	±30%	70-130%
Chromium (hexavalent)	18540-29-9	18.4	0.5	N/A	Chromium (hexavalent) – EPA Method 7196	0.5	±30%	70-130%
Iron	7439-89-6	152	5	35,000	EPA Method 6010 EPA Method 200.8	5	±30%	70-130%
Mercury	7439-97-6	2.09	0.2	0.33	EPA Method 200.8 EPA Method 7471	0.2	±30%	70-130%
Thallium	7440-28-0	1.59	0.5	N/A	EPA Method 6010 EPA Method 200.8	0.5	±30%	70-130%
Uranium (total)	7440-61-1	1.32	1	N/A	EPA Method 200.8 Uranium – kinetic phosphorescence absorption	1	±30%	70-130%

Table A1-9. Saturated Sediment Analytical Performance Requirements for Nonradiological Chemical Constituents. (3 Pages)

COPC	CAS #	Preliminary Action Level			Name/Analytical Technology[c]	Target-Required Quantitation Limits[d]	Precision Soil[e]	Accuracy Soil[e]
		Target Method B[a] (mg/kg)	Analytical Detection Limits (mg/kg)	Background[b] (mg/kg)		Soil – Other Low Conc. (mg/kg)		
Inorganics								
Chloride	16887-00-6	1,000	2	100	EPA Method 300.0	2	±30%	70-130%
Cyanide	57-12-5	0.8	0.5	N/A	EPA Method 335.2 EPA Method 9010 EPA Method 9012	0.5	±30%	70-130%
Nitrate	14797-55-8	40	2.5	52	EPA Method 300.0	2.5	±30%	70-130%
Nitrite	14797-65-0	4	2.5	N/A	EPA Method 300.0	2.5	±30%	70-130%
Sulfate	14808-79-8	1,030	5	237	EPA Method 300.0	5	±30%	70-130%
Nitrogen in nitrate and nitrite	NO2+NO3-N	4	0.75	N/A	EPA Method 335.2	0.75	±30%	70-130%
Volatile Organics								
Chloroform	67-66-3	0.0381	0.005	N/A	EPA Method 8260	0.005	±30%	50-150%
Methylene chloride	75-09-2	0.0218	0.005	N/A	EPA Method 8260	0.005	±30%	50-150%
Semivolatile Organics								
Bis(2-ethylhexyl)phthalate	117-81-7	13.9	0.330	N/A	EPA Method 8270	0.330	±30%	50-150%
Pentachlorophenol	87-86-5	0.0115	0.330	N/A	EPA Method 8270	0.330	±30%	50-150%

Table A1-9. Saturated Sediment Analytical Performance Requirements for Nonradiological Chemical Constituents. (3 Pages)

COPC	CAS #	Preliminary Action Level			Name/Analytical Technology[c]	Target-Required Quantitation Limits[d]	Precision Soil[e]	Accuracy Soil[e]
		Target Method B[a] (mg/kg)	Analytical Detection Limits (mg/kg)	Background[b] (mg/kg)		Soil – Other Low Conc. (mg/kg)		

NOTE: Different methods are run for different laboratories.

[a] WAC 173-340-740(3), "Unrestricted Land Use Soil Cleanup Standards," "Method B Soil Cleanup Levels for Unrestricted Land Use," soil cleanup levels. This is the protection of groundwater concentrations determined by the three-phase partitioning model.

[b] Soil background concentration provided by either DOE/RL-92-24, *Hanford Site Background: Part 1, Soil Background for Nonradioactive Analytes*, or Ecology 94-115, *Natural Background Soil Metals Concentrations in Washington State.*

[c] For EPA Method 200.8, see EPA/600/R-94/111, *Methods for the Determination of Metals in Environmental Samples, Supplement 1.* For EPA Methods 335.2 and 300.0, see EPA/600/4-79/020, *Methods of Chemical Analysis of Water and Wastes.* For four-digit EPA methods, see SW-846, *Test Methods for Evaluating Solid Waste: Physical/Chemical Methods, Third Edition; Final Update IV-B.*

[d] Target-required quantitation limits are based on analytical detection limits. This generally is below the target Method B limits; however, in some cases the detection level is above the target Method B levels and, thus, the preliminary action level is adjusted to the detection level or background.

[e] Accuracy criteria for inorganic analyses for associated batch matrix spike recoveries. Evaluation based on statistical control of laboratory control samples also performed. Precision criteria for batch laboratory replicate matrix spike sample analyses or replicate sample analyses. Accuracy criteria for organic analyses for associated batch laboratory control sample recoveries. Laboratories must meet statistically based control if more stringent. Additional analyte-specific evaluations also performed for matrix spikes, and surrogates, as appropriate to the method. Precision criteria for batch laboratory replicate matrix spike analyses.

CAS = Chemical Abstracts Service.
COPC = contaminant of potential concern.
EPA = U.S. Environmental Protection Agency.
N/A = not applicable.
WAC = *Washington Administrative Code.*

Table A1-10. Groundwater Analytical Performance Requirements for Radiological Constituents. (2 Pages)

COPC	CAS #	Background	Preliminary Groundwater Action Level[a] (pCi/L)	Name/ Analytical Technology	Target-Required Quantitation Limits[b] Groundwater (pCi/L)	Precision Water[c]	Accuracy Water[c]
Radionuclides							
Am-241	14596-10-2	N/A	15	Isotopic americium – AEA	1	±30%	70-130%
Cs-137	10045-97-3	N/A	200	GEA	15	±30%	70-130%
Co-60	10198-40-0	N/A	100	GEA	25	±30%	70-130%
C-14	14762-75-5	N/A	2,000	C-14 – liquid scintillation	200	±30%	70-130%
I-129	15046-84-1	N/A	1	I-129 – liquid scintillation	1	±30%	70-130%
Np-237	13994-20-2	N/A	15	Np-237 – AEA	1	±30%	70-130%
Pu-238	13981-16-3	NA	15	Isotopic plutonium – AEA	1	±30%	70-130%
Pu-239/240	Pu-239/240	N/A	15	Isotopic plutonium – AEA	1	±30%	70-130%
Sr-89/90	RAD-SR	N/A	8	Total beta radiostrontium – GPC	2	±30%	70-130%
Tc-99	14133-76-7	N/A	900	Tc-99 – liquid scintillation or GPC	15	±30%	70-130%
Th-232	Th-232	N/A	15	Thorium isotopic – AEA	1	±30%	70-130%
Th-234	Th-234	N/A	401	Thorium isotopic – AEA	1	±30%	70-130%
U (total)[d]	7440-61-1	9.85	30 µg/L	EPA Method 200.8 Uranium – kinetic phosphorescence absorption	1 µg/ L	±30%	70-130%
Tritium	10028-17-8	N/A	20,000	Tritium – liquid scintillation	30	±30%	70-130%

Table A1-10. Groundwater Analytical Performance Requirements for Radiological Constituents. (2 Pages)

COPC	CAS #	Background	Preliminary Groundwater Action Level[a] (pCi/L)	Name/ Analytical Technology	Target-Required Quantitation Limits[b]	Precision Water[c]	Accuracy Water[c]
					Groundwater (pCi/L)		

NOTE: Different methods are run for different laboratories.

[a]The most conservative value from 40 CFR 141, "National Preliminary Drinking Water Regulations"; 40 CFR 143, "National Secondary Drinking Water Regulations"; and WAC 173-340-720, "Ground Water Cleanup Standards."

[b]Target-required quantitation limits are based on providing limits low enough to evaluate contaminants below the preliminary action level. In some cases, this is difficult due to other contaminant concentration levels (I-129) and thus the preliminary action level may need to be adjusted.

[c]Accuracy criteria is the minimum for associated batch laboratory control sample percent recoveries. With the exception of GEA, additional analysis-specific evaluations also performed for matrix spikes, tracers, and carriers, as appropriate to the method.

[d]Uranium-233, U-234, U-235, and U-238 are listed as COPCs in Table A1-3. Isotopic analysis of these isotopes will be performed to support the uranium source investigation in the vicinity of WMA-B/BX/BY and the BY Cribs and are included in Table A1-12. Isotopic analysis also may be performed if total uranium concentration exceeds the preliminary action level of 30 µg/L.

For EPA Method 200.8, see EPA/600/R-94/111, *Methods for the Determination of Metals in Environmental Samples, Supplement 1.*

AEA = alpha energy analysis.
CAS = Chemical Abstract Service.
CFR = *Code of Federal Regulations.*
COPC = contaminant of potential concern.
EPA = U.S. Environmental Protection Agency.
GEA = gamma energy analysis.
GPC = gas proportional counting.
N/A = not applicable.
WAC = *Washington Administrative Code.*
WMA = waste management area.

Table A1-11. Groundwater Analytical Performance Requirements for Nonradiological Chemical Constituents. (3 Pages)

COPCs	CAS #	Preliminary Action Level			Name/Analytical Technology[c]	Target-Required Quantitation Limits	Precision Water	Accuracy Water
		Target Level[a] (µg/L)	Analytical Detection Limits (µg/L)	Background[b] (µg/L)		Water – Low Conc. (µg/L)		
Metals								
Aluminum	7429-90-5	50 to 200	6	11.7	EPA Method 6010 EPA Method 200.8	6	±30%[d]	70-130%[d]
Antimony	7440-36-0	6	5	69.8	EPA Method 6010 EPA Method 200.8	5	±30%[d]	70-130%[d]
Arsenic	7440-38-2	11.8	10	11.8	EPA Method 6010 EPA Method 200.8	10	±30%[d]	70-130%[d]
Cadmium	7440-43-9	5	2	1.29	EPA Method 6010 EPA Method 200.8	2	±30%[d]	70-130%[d]
Chromium	7440-47-3	100	5	3.17	EPA Method 6010 EPA Method 200.8	5	±30%[d]	70-130%[d]
Chromium (hexavalent)	18540-29-9	48	10	N/A	Chromium (hexavalent) – EPA Method 7196	10	±30%[d]	70-130%[d]
Iron	7439-89-6	1,104	50	1,104	EPA Method 6010	50	±30%[d]	70-130%[d]
Mercury	7439-97-6	2	.2	0.85	EPA Method 200.8	.2	±30%[d]	70-130%[d]
Sodium	7782-23-5	250,000	50,000	32,919	EPA Method 6010 EPA Method 200.8	50,000	±30%[d]	70-130%[d]
Thallium	7440-28-0	1.87	1	1.87	EPA Method 6010 EPA Method 200.8	1	±30%[d]	70-130%[d]
Uranium (total)	7440-61-1	30	1	9.85	EPA Method 200.8 Uranium – kinetic phosphorescence absorption	1	±30%[d]	70-130%[d]

Table A1-11. Groundwater Analytical Performance Requirements for Nonradiological Chemical Constituents. (3 Pages)

COPCs	CAS #	Preliminary Action Level			Name/Analytical Technology[c]	Target-Required Quantitation Limits	Precision Water	Accuracy Water
		Target Level[a] (µg/L)	Analytical Detection Limits (µg/L)	Background[b] (µg/L)		Water – Low Conc. (µg/L)		
Inorganics								
Chloride	16887-00-6	250,000	200	28,500	EPA Method 300.0	200	±30%[d]	70-130%[d]
Cyanide	57-12-5	200	5	9.52	EPA Method 335.2 EPA Method 9010 EPA Method 9012	5	±30%[d]	70-130%[d]
Nitrate	14797-55-8	10	250	12,400	EPA Method 300.0	250	±30%[d]	70-130%[d]
Nitrite	14797-65-0	1	250	130	EPA Method 300.0	250	±30%[d]	70-130%[d]
Nitrogen in nitrate and nitrite	NO2+NO3-N	4	75	N/A	EPA Method 335.2	750	±30%[d]	70-130%[d]
Sulfate	14808-79-8	250,000	500	54,950	EPA Method 300.0	500	±30%[d]	70-130%[d]
Volatile Organics								
Chloroform	67-66-3	7.17	5	N/A	EPA Method 8260	5	±30%[e]	50-150%[e]
Methylene chloride	75-09-2	5	5	N/A	EPA Method 8260	5	±30%[e]	50-150%[e]
Semivolatile Organics								
Bis(2-ethylhexyl)phthalate	117-81-7	6.25	5	N/A	EPA Method 8270	5	±30%[e]	50-150%[e]
Pentachlorophenol	108-95-2	0.729	0.330	N/A	EPA Method 8270	5	±30%[e]	50-150%[e]

Table A1-11. Groundwater Analytical Performance Requirements for Nonradiological Chemical Constituents. (3 Pages)

COPCs	CAS #	Preliminary Action Level			Name/Analytical Technology[c]	Target-Required Quantitation Limits	Precision Water	Accuracy Water
		Target Level[a] (µg/L)	Analytical Detection Limits (µg/L)	Background[b] (µg/L)		Water – Low Conc. (µg/L)		

NOTE: Different methods are run for different laboratories.

[a]The most conservative value from 40 CFR 141, "National Primary Drinking Water Regulations"; 400 CFR 143, "National Secondary Drinking Water Standards"; and WAC 173-340-720(4), "Ground Water Cleanup Standards," "Method B Cleanup Levels for Potable Ground Water," groundwater cleanup levels.

[b]Groundwater background concentration provided by DOE/RL-92-23, *Hanford Site Groundwater Background*, and DOE/RL-96-61, *Hanford Site Background: Part 3, Groundwater Background.*

[c]For EPA Method 200.8, see EPA/600/R-94/111, *Methods for the Determination of Metals in Environmental Samples, Supplement 1*. For EPA Methods 335.2 and 300.0, see EPA/600/4-79/020, *Methods of Chemical Analysis of Water and Wastes*. For 4-digit EPA methods, see SW-846, *Test Methods for Evaluating Solid Waste: Physical/Chemical Methods, Third Edition; Final Update IV-B.*

[d]Precision and accuracy requirements are identified and defined in the referenced EPA procedures. Accuracy criteria for associated batch matrix spike percentage recoveries. Evaluation based on statistical control of laboratory control sample also preformed. Precision criteria based on batch laboratory replicate matrix spike sample analyses or replicate sample analyses.

[e]Accuracy criteria are the minimum for associated batch laboratory control sample percentage recoveries. Laboratories must meet statistically based control if more stringent. Additional analyte-specific evaluations also performed for matrix spike and surrogates as appropriate to the method. Precision criteria as based on laboratory replicate matrix spike sample analyses.

CAS = Chemical Abstracts Service.
COPC = contaminant of potential concern.
CFR = *Code of Federal Regulations.*
EPA = U.S. Environmental Protection Agency.
N/A = not applicable.
WAC = *Washington Administrative Code.*

Table A1-12. Analytical Performance Requirements for Physical, Hydraulic, and Model Development Parameters. (2 Pages)

Property	Parameter	Method	Target-Required Quantitation Limits	Precision Required	Accuracy Required
Physical parameters	Particle-size distribution	ASTM D422-63(2007)	N/A	N/A	N/A
	Spectral-gamma borehole logging	Borehole logging (16 or 32 ft/h rate if single-cased, 60 ft/h if dual-wall casing – TBD)	N/A	N/A	N/A
	Neutron moisture logging	Borehole logging (40 ft/h rate)	N/A	N/A	N/A
	Bulk density	ASTM D2937-04	N/A	N/A	N/A
	Lithology	Hanford Site methods	N/A	N/A	N/A
Hydraulic and transport parameters	Moisture content	ASTM D2216	N/A	N/A	N/A
	Saturated hydraulic conductivity	ASTM D50840-03	N/A	N/A	N/A
	Unsaturated hydraulic conductivity (vadose-zone analysis)	ASA, 1986	N/A	N/A	N/A
	Water level	Field measurement	N/A	±0.006 m	±0.006 m
	Pumping performance, drawdown, and flow rate	Well development	N/A	N/A	±0.006 m
	Uranium isotopic signatures	Lawrence Berkeley National Laboratory	N/A	N/A	N/A
	Cation-exchange capacity	Routson et al., 1973	N/A	N/A	N/A
	K_d (contaminant-specific)	ASTM D3987-06	N/A	N/A	±25%
	Specific conductance	Field measurement	N/A	N/A	N/A
	Temperature	Field measurement	N/A	+1 °C	+1 °C
	Dissolved oxygen	Field measurement	N/A	0.1 mg/L	±25%
	Turbidity	Field measurement	<5 NTU	N/A	±1%

Table A1-12. Analytical Performance Requirements for Physical, Hydraulic, and Model Development Parameters. (2 Pages)

Property	Parameter	Method	Target-Required Quantitation Limits	Precision Required	Accuracy Required
Model development parameters	pH	pH probe	N/A	±0.1 pH	±0.1 pH
	Conductivity	Conductivity probe	N/A	±20%	±10%
	Alkalinity	Titration	5 mg/L	±20%	±10%
	Anions/organic acids	Ion chromatography	TBD	±20%	±10%
	RCRA metals	Inductively coupled plasma – mass spectrometry – Method 6020	TBD	±20%	±10%
	Tc-99, tritium, U-233, U-234, U 235, U-236, U-238, I-129	Inductively coupled plasma – mass spectrometry – Method 6010B	TBD	±20%	±10%
	Cations	Inductively coupled plasma – optical emission spectrometry	TBD	±20%	±10%
	Total organic carbon (sediments)	Combustion/chemical oxidation carbon analyzer	25 mg/kg	±20%	±10%
	Total inorganic carbon (sediments)	Combustion/chemical oxidation carbon analyser	12.5 mg/kg	±20%	±10%
	Gross alpha/beta	Liquid scintillation	5 pCi/g alpha 10 pCi/g beta	±25%	±20%

ASA, 1986, *Methods of Soil Analysis, Part 1 – Physical and Mineralogical Methods*, Chapter 31.
ASTM D422-63(2007), *Standard Test Methods for Particle-Size Analysis of Soils.*
ASTM D2937-04, *Standard Test Method for Density of Soil in Place by the Drive-Cylinder Method.*
ASTM D2216-05, *Standard Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass.*
ASTM D5084-03, *Standard Test Methods for Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter.*
Routson et al., 1973, "A Column Cation-Exchange-Capacity Procedure for Low-Exchange Capacity Sands."

For four-digit EPA methods, see SW-846, *Test Methods for Evaluating Solid Waste: Physical/Chemical Methods, Third Edition; Final Update IV-B.*

ASTM = American Society for Testing and Materials.
K_d = distribution coefficient.
N/A = not applicable.
NTU = nephelometric turbidity unit.
RCRA = *Resource Conservation and Recovery Act of 1976.*
TBD = to be determined.

A2.0 QUALITY ASSURANCE PROJECT PLAN

The quality assurance project plan (QAPjP) establishes the quality requirements for environmental data collection, including sampling, field measurements, and laboratory analysis. The QAPjP complies with the requirements of the following:

- DOE O 414.1C, *Quality Assurance*
- 10 CFR 830, Subpart A, "Quality Assurance Requirements"
- EPA/240/B-01/003, *EPA Requirements for Quality Assurance Project Plans*, EPA QA/R-5.

The following sections describe the quality requirements and controls applicable to this investigation. Correlation between EPA/240/B-01/003 requirements and information in this SAP is provided in Table A2-1.

Table A2-1. Correlation Between EPA QA/R-5 Requirements and the Sampling and Analysis Plan. (2 Pages)

EPA QA/R-5 Criteria	EPA QA/R-5 Title	Reference Section
Project Management	Project/Task Organization	A2.1
	Problem Definition/Background	A1.0
	Project/Task Description	A1.0, A2.4
	Quality Objectives and Criteria	A2.2
	Special Training/Certification	A2.3
	Documents and Records	A2.4
Data Generation and Acquisition	Sampling Process Design	A2.5, A3.1, A3.2, A3.3
	Sampling Methods	A2.5.1
	Sample Handling and Custody	A2.5.3
	Sample Preservation Methods	A2.5.4
	Analytical Methods	A2.5.5; Tables A1-5, A1-6, A1-7, A1-10, and A1-11
	Quality Control	A2.5.6
	Instrument/Equipment Testing, Inspection, and Maintenance	A2.5.7
	Instrument/Equipment Calibration and Frequency	A2.5.8
	Inspection/Acceptance of Supplies and Consumables	A2.5.9
	Nondirect Measurements	A2.5.10
	Data Management	A2.5.11
Assessment and Oversight	Assessments and Response Actions	A2.6.1
	Reports to Management	A2.6.2

Table A2-1. Correlation Between EPA QA/R-5 Requirements and the Sampling and Analysis Plan. (2 Pages)

EPA QA/R-5 Criteria	EPA QA/R-5 Title	Reference Section
Data Validation and Usability	Data Review, Verification, and Validation	A2.7
	Verification and Validation Methods	A2.7.1, A2.7.2
	Reconciliation with User Requirements	A2.7.3

EPA/240/B-01/003, *EPA Requirements for Quality Assurance Project Plans*, EPA QA/R-5.

EPA = U.S. Environmental Protection Agency.

Quality assurance (QA) requirements are implemented according to the internal Fluor Hanford, Inc. (FH) QA program. The QA program description document describes how FH implements the QA requirements conveyed in DOE O 414.1C and 10 CFR 830.121, "Quality Assurance Program (QAP)," and how the *Hanford Federal Facility Agreement and Consent Order* (Tri-Party Agreement) (Ecology et al., 1989) and Hanford Site internal laboratory QA requirements apply to FH environmental QA program plans.

All work performed under this SAP will be performed in compliance with the FH QA Program plan, the FH Soil & Groundwater Remediation Project plan, or subsequent and equivalent FH quality program plans. Field sample collection and documentation activities will be performed according to applicable FH procedures.

A2.1 PROJECT/TASK ORGANIZATION

The project organization is described in the subsections that follow and is shown in Figure A2-1.

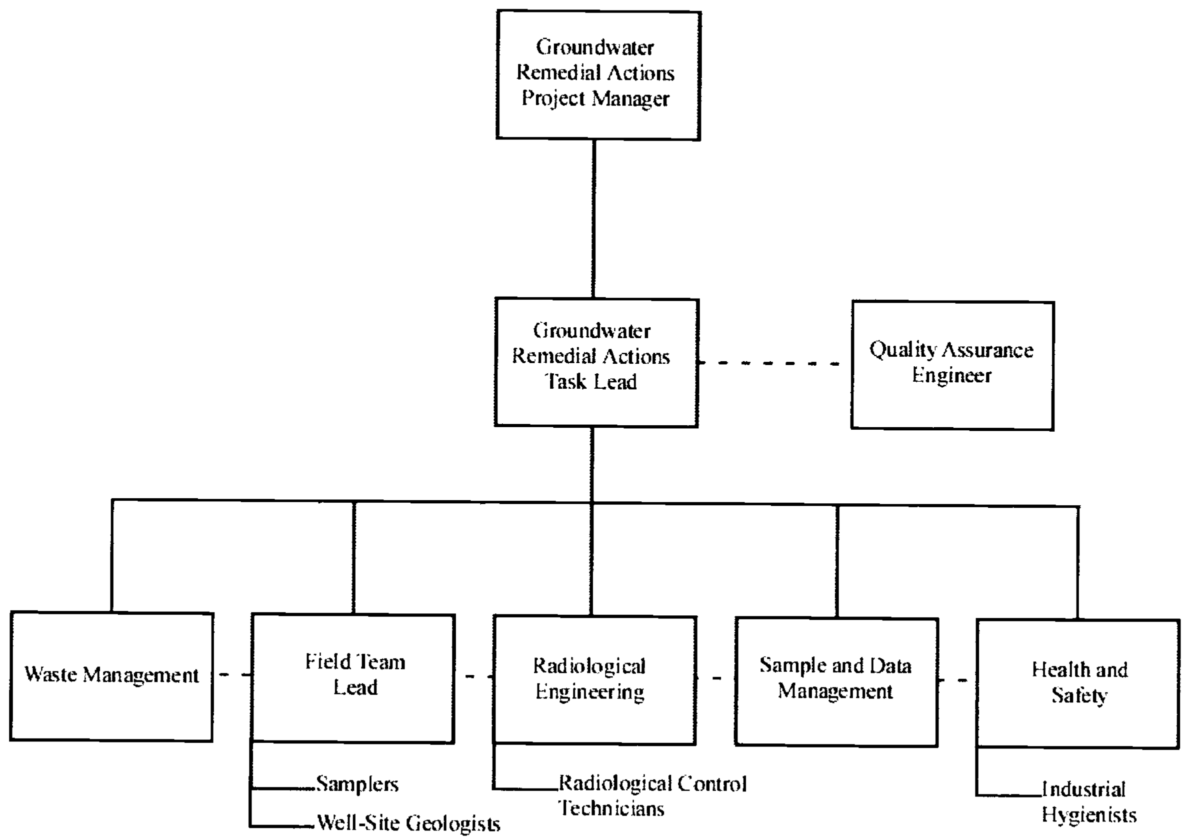
A2.1.1 Groundwater Remedial Actions Project Manager

The Groundwater Remedial Actions project manager provides oversight for all activities and coordinates with the U.S. Department of Energy, Richland Operations Office (RL) and the regulators in support of sampling activities. In addition, support is provided to the task lead to ensure that work is performed safely and cost effectively.

A2.1.2 Groundwater Remedial Actions Task Lead

The Groundwater Remedial Actions task lead is responsible for direct management of sampling documents and requirements, field activities, and subcontracted tasks. The task lead ensures that the field team lead, samplers, and others responsible for implementation of this SAP are provided with current copies of this document and any revisions thereto. The task lead works closely with QA, Health and Safety, and the field team lead to integrate these and the other lead disciplines in planning and implementing the work scope. The task lead also coordinates with, and reports to, RL, the regulators, and the Hanford Management Contractor on all sampling activities.

Figure A2-1. 200-BP-5 Groundwater Operable Unit Project/Task Organization.



A2.1.3 Quality Assurance Engineer

The QA engineer is matrixed to the Groundwater Remedial Actions task lead and is responsible for QA issues on the project. Responsibilities include overseeing implementation of the project QA requirements; reviewing project documents, including SAPs (and the QAPjP); and participating in QA assessments on sample collection and analysis activities, as appropriate.

A2.1.4 Waste Management

The Waste Management lead communicates policies and procedures and ensures project compliance for storage, transportation, disposal, and waste tracking in a safe and cost-effective manner. Other responsibilities include identifying waste management sampling/characterization requirements to ensure regulatory compliance interpretation (e.g., with WAC 173-303, "Dangerous Waste Regulations") of the characterization data to generate waste designations, profiles, and other documents that confirm compliance with the applicable waste control plan.

A2.1.5 Field Team Lead

The field team lead has the overall responsibility for planning, coordinating, and executing the field characterization activities. Specific responsibilities include converting the sampling design requirements into field task instructions that provide specific direction for field activities. Responsibilities also include directing training, mock-ups, and practice sessions with field personnel to ensure that the sampling design is understood and can be performed as specified. The field team lead communicates with the Groundwater Remedial Actions task lead to identify field constraints that could affect the sampling design. In addition, the field team lead directs the procurement and installation of materials and equipment needed to support the fieldwork.

The field team lead oversees field-sampling activities that include sample collection, packaging, provision of certified clean sampling bottles/containers, documentation of sampling activities in controlled logbooks, chain-of-custody documentation, and packaging and transportation of samples to the laboratory or shipping center.

The field team leads, samplers, and others responsible for implementation of this SAP and the QAPjP will be provided with current copies of this document and any revisions thereto.

A2.1.6 Radiological Engineering

The Radiological Engineering lead is responsible for the radiological engineering and health physics support within the project. Specific responsibilities include conducting as-low-as-reasonably-achievable (ALARA) reviews, exposure and release modeling, and radiological controls optimization for all work planning. In addition, radiological hazards are identified and appropriate controls are implemented to maintain worker exposures to the hazards ALARA. Radiological Engineering interfaces with the project Health and Safety representative and plans and directs radiological control technician support for all activities.

A2.1.7 Sample and Data Management

The Sample and Data Management organization selects the laboratories to perform the analyses. This organization also ensures that the laboratories conform to Hanford Site internal laboratory QA requirements (or their equivalent), as approved by RL, EPA, and the Washington State Department of Ecology. The Sample and Data Management organization initiates audits of the laboratories periodically to ensure compliance. Sample and Data Management receives analytical data from the laboratories, makes the data entry into the HEIS database, and arranges for data validation. Validation will be performed on completed data packages (including quality control [QC] samples) by FH's Environmental Information Services group or by a qualified independent contractor.

A2.1.8 Health and Safety

The responsibilities of the Health and Safety organization include coordinating industrial safety and health support within the project as carried out through safety and health plans, job hazard analyses, and other pertinent safety documents required by Federal regulation or by FH work requirements. In addition, Health and Safety provides assistance to project personnel in complying with applicable health and safety standards and requirements. Personnel protective clothing requirements are coordinated with Radiological Engineering.

A2.2 QUALITY OBJECTIVES AND CRITERIA FOR MEASUREMENT DATA

Laboratory analytical detection limits and the precision and accuracy requirements for each analysis to be performed are summarized in Tables A1-6, A1-7, A1-10, and A1-11. Performance criteria for physical, hydrologic, and model parameter testing are found in Table A1-12.

A2.3 SPECIAL TRAINING REQUIREMENTS AND CERTIFICATION

A graded approach is used to ensure that workers receive a level of training that is commensurate with their responsibilities and that complies with applicable DOE orders and government regulations. The field team lead, in coordination with the remediation task lead, will ensure that all field personnel meet all special training requirements.

Field personnel typically will have completed the following training before starting work:

- Occupational Safety and Health Administration 40-Hour Hazardous Waste Worker Training
- 8-Hour Hazardous Waste Worker Refresher Training (as required)
- Radiation Worker II Training
- Hanford General Employee Training.

A2.4 DOCUMENTATION AND RECORDS

As indicated in Section A2.1.2, the FH Groundwater Remedial Actions task lead is responsible for ensuring that the field team lead, samplers, and others responsible for implementation of this SAP are provided with current copies of this document and any revisions thereto.

Field sampling and well-site activity documentation will be performed in accordance with FH procedures pertaining to the following:

- Notebooks and logbooks
- Geologic logging
- Groundwater sampling
- Calibration of field equipment
- Sampling documentation
- Geophysical logging (S. M. Stoller procedures)
- Chain-of-custody/sample analysis requests
- Sample packaging and shipping.

Laboratory analytical documentation will be in accordance with RFSH-SOW-93-0003, *Statement of Work for Environmental and Waste Characterization Analytical Services*, for groundwater sampling. Overall project documentation will be in accordance with the FH procedures standards-based management system.

Data and information generated from the sampling activities will be used to support characterization efforts and to evaluate remedial alternatives for the 200-BP-5 Groundwater OU. The data and information will be incorporated into project documents, including a borehole summary report and RI report. Data and information from this sampling activity also may be included (if available at the time of document preparation) in the FS planning documents for the 200-BP-5 Groundwater OU.

A2.5 DATA/MEASUREMENT ACQUISITION

The following subsections present the requirements for sampling methods, sample handling and custody, analytical methods, and field and laboratory QC. The requirements for instrument calibration and maintenance, supply inspections, and data management also are addressed.

A2.5.1 Sampling Methods Requirements

Sampling associated with this SAP will be performed in accordance with established sampling practices and requirements pertaining to sample collection, collection equipment, and sample handling. The procedures to be implemented in the field should be in accordance with those outlined in the Hanford Site internal laboratory QA requirements and the applicable FH procedures for the sampling activities listed in Section A3.4 of this SAP.

The field team lead and the task lead are responsible for ensuring that all field procedures are followed completely and that field personnel are adequately trained. The field team lead and the task lead must document situations that may impair the usability of the samples and/or data in the field logbook or nonconformance report forms in accordance with internal corrective action procedures, as appropriate. The field team lead will note any deviations from the standard procedures for sample collection, COPCs, sample transport, or monitoring that occur.

A2.5.2 Sampling Identification

A sample and data-tracking database will be used to track the samples from the point of collection through the laboratory analysis process. The HEIS database is the repository for laboratory analytical results. The HEIS sample numbers will be issued to the sampling organization for this project and are to be carried through the laboratory data-tracking system.

A2.5.3 Sample Handling, Shipping, and Custody Requirements

All sample handling, shipping, and custody requirements will be performed in accordance with applicable FH procedures pertaining to sample packaging and shipping and chain-of-custody/ sample analysis requests.

A2.5.4 Sample Preservation, Containers, and Holding Times

Sample preservation, container, and holding time requirements will be prepared for specific sampling events, as specified on the sampling authorization forms and chain-of-custody forms in accordance with the requirements specified in RFSH-SOW-93-0003 and the specific analytical method.

A2.5.5 Analytical Methods Requirements

Analytical parameters and methods are listed in Tables A1-6 through A1-12. Laboratory-specific standard operating procedures for analytical methods are described in the Hanford Site internal laboratory QA requirements.

Errors reported by the laboratories are reported to the Sample and Data Management project coordinator, who initiates a Sample Disposition Record in accordance with FH procedures. This process is used to document analytical errors and to establish resolution with the project task lead.

A2.5.6 Quality Control Requirements

The QC procedures described in the Hanford Site internal laboratory QA requirements must be followed in the field and laboratory to ensure that reliable data are obtained. When performing this field-sampling effort, care should be taken to prevent the cross-contamination of sampling equipment, sample bottles, and other equipment that could compromise sample integrity.

Table A2-2 lists the field QC requirements for sampling. If only disposable equipment is used or if equipment is dedicated to a particular well, then an equipment rinsate blank is not required. If volatile organic compound samples are not collected, then a field transfer blank is not required. Field transfer blanks are not required when simply transferring samples to the field gas chromatograph for analysis.

Table A2-2. Field Quality Control Requirements.

Sample Type	Frequency	Purpose
Duplicate	5% (1 sample in 20)	To check the precision of the laboratory analyses
Equipment rinsate	One per 10 well trips	To check the effectiveness of the decontamination process
Field transfer blank	One per day when volatile organics are sampled	To check for contamination during transport

Laboratory QC sample requirements are specified in RFSH-SOW-93-0003.

A2.5.7 Instrument/Equipment Testing, Inspection, and Maintenance Requirements

All onsite environmental instruments shall be tested, inspected, and maintained in accordance with manufacturer's specifications and FH procedures pertaining to control and calibration of field and monitoring instruments. The results from all testing, inspection, and maintenance activities shall be recorded in the geologist's daily field activity report, in accordance with applicable FH procedures.

A2.5.8 Instrument Calibration and Frequency

All onsite environmental instruments shall be calibrated in accordance with manufacturer's specifications and FH procedures pertaining to the following:

- Calibration requirements of field measurement equipment
- Control of monitoring instruments.

The results from all testing, inspection, and maintenance activities shall be recorded in the field activity report in accordance with applicable FH procedures. Tags will be attached to all field screening and onsite analytical instruments, noting the date when the instrument was last calibrated and the calibration expiration date.

A2.5.9 Inspection/Acceptance Requirements for Supplies and Consumables

All subject activities shall meet requirements of the Hanford Site internal laboratory QA requirements. The lot number from the manufacturer-certified, pre-cleaned sample containers shall be recorded in the sampler's logbook.

Supplies and consumables procured by FH that are used in support of sampling and analysis activities are procured in accordance with internal work requirements and processes that describe the FH acquisition system and the responsibilities and interfaces necessary to ensure that structures, systems, and components, or other items and services procured/acquired for FH, meet the specific technical and quality requirements. The procurement process ensures that purchased items and services comply with applicable procurement specifications. Supplies and consumables are checked and accepted by users before use.

Supplies and consumables procured by the analytical laboratories are procured, checked, and used in accordance with the laboratories' QA plans.

A2.5.10 Nondirect Measurements

Nondirect measurement sources (e.g., computer databases, programs, and literature files) were used during the DQO process to assist with well-placement decisions and for the development of the list of COPCs. No further use of nondirect measurements is required to support the scope of this SAP.

A2.5.11 Data Management

Data resulting from the implementation of this QAPjP shall be managed and stored in accordance with applicable programmatic requirements governing data management procedures. At the direction of the task lead, all analytical data packages shall be subject to final technical review by qualified personnel before the results are submitted to the regulatory agencies or before inclusion in reports. Electronic data access, when appropriate, shall be via a database (e.g., HEIS or a project-specific database). Where electronic data are not available, hard copies shall be provided in accordance with Section 9.6 of the Tri-Party Agreement (Ecology et al., 1989).

Planning for sample collection and analysis shall be in accordance with the programmatic requirements governing fixed laboratory sample collection activities, as discussed in the sample team's procedures. In the event that specific procedures do not exist for a particular work evolution, or if additional guidance to complete certain tasks is needed, a work package will be developed to adequately control the activities, as appropriate. Examples of the sample team's requirements include activities associated with the following:

- Chain-of-custody/sample analysis requests
- Project and sample identification for sampling services
- Control of certificates of analysis
- Logbooks and checklists
- Sample packaging and shipping.

Approved work control packages and procedures will be used to document radiological measurements when implementing this SAP. Examples of the types of documentation for field radiological data include the following:

- Instructions regarding the minimum requirements for documenting radiological controls information in accordance with 10 CFR 835, "Occupational Radiation Protection"
- Instructions for managing the identification, creation, review, approval, storage, transfer, and retrieval of Hanford Site radiological records
- The minimum standards and practices necessary for preparing, performing, and retaining radiological-related records
- The indoctrination of personnel on the development and implementation of survey/sample plans
- The requirements associated with preparing and transporting regulated material.

Data will be cross-referenced between laboratory analytical data and radiation measurements to facilitate interpreting the investigation results.

A2.6 ASSESSMENT/OVERSIGHT

A2.6.1 Assessments and Response Actions

FH management, Regulatory Compliance, Quality, and/or Health and Safety organizations may conduct random surveillances and assessments to verify compliance with the requirements outlined in this SAP, project work packages, the project quality management plan, procedures, and regulatory requirements. Other than the final walkdown of the completed wells, no other specific assessments are planned for this activity. The final walkdown will be documented in a QA surveillance report.

Deficiencies identified during these assessments shall be reported to the Groundwater Remedial Actions task lead. When appropriate, corrective actions will be taken by the project lead in accordance with the Hanford Site internal laboratory QA requirements to minimize recurrence.

A2.6.2 Reports to Management

Management shall be made aware of all deficiencies identified by self-assessments. Identified deficiencies shall be reported to the FH technical project lead.

A2.7 DATA REVIEW, VERIFICATION, VALIDATION, AND USABILITY REQUIREMENTS

A2.7.1 Data Verification and Usability Methods

Data review and verification are performed by the laboratory to confirm that sampling and chain-of-custody documentation are complete. This review shall include tying sample numbers to specific sampling location(s), reviewing sample collection dates and sample preparation and analysis dates to assess whether holding times have been met, and reviewing QC data to determine whether analyses met the data quality requirements specified in this SAP.

All data verification and usability assessments shall be performed in accordance with the Hanford Site internal laboratory QA requirements.

A2.7.2 Data Validation

Data validation generally is performed by an independent third party not involved in sampling, analysis, or assessment. The FH Soil & Groundwater Remediation Project will evaluate the data packages to be submitted to the data validation contractor. Part of the evaluation for selection of the data packages is to choose packages in which contaminant concentrations are high, mid-range, and low. Thus, various packages from each will be selected for validation. Five percent of the results will undergo Level C validation, as defined by FH Soil & Groundwater Remediation Project validation procedures.

A2.7.3 Data Quality Assessment

The data quality assessment process compares completed field-sampling activities to those proposed in corresponding sampling documents and provides an evaluation of the resulting data. The purpose of the data evaluation is to determine if quantitative data are of the correct type and are of adequate quality and quantity to meet the project DQOs. The EPA data quality assessment process (EPA/240/B-06/002, *Data Quality Assessment: A Reviewers Guide*, EPA QA/G-9R) identifies five steps for evaluating data generated from this project, as summarized below:

1. Review DQOs and sampling design: This step requires a comprehensive review of the sampling and analytical requirements outlined in the project-specific DQO summary report and SAP.
2. Conduct a preliminary data review: In this step, a comparison is made between the actual QA/QC achieved (e.g., detection limits, precision, accuracy) and the requirements determined during the DQO process. Any significant deviations will be documented. Basic statistics will be calculated from the analytical data at this point, as appropriate to the data set, including an evaluation of the distribution of the data and in accordance with the DQOs.

3. Select the statistical test. Using the data evaluated in step 2, an appropriate statistical hypothesis test is selected and justified.

4. Verify the assumptions: In this step, the validity of the data analyses is assessed by determining if the data support the underlying assumptions necessary for the analyses or if the data set must be modified (e.g., transposed, augmented with additional data) before further analysis. If one or more assumptions are questioned, step 3 is repeated.

5. Draw conclusions from the data: The statistical test is applied in this step, and the results either reject the null hypothesis or fail to reject the null hypothesis. If the latter is true, the data should be analyzed further. If the null hypothesis is rejected, the overall performance of the sampling design should be evaluated by performing a statistical power calculation to assess the adequacy of the sampling design.

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A3.0 FIELD-SAMPLING PLAN

A3.1 SAMPLING OBJECTIVES

The objective of the field-sampling plan is to clearly identify project sampling and analysis activities. The field-sampling plan uses the sampling design identified during the DQO process and presents the design primarily using figures and tables whenever possible to identify sampling locations, the total number of samples to be collected, sampling procedures to be implemented, analyses to be performed, and sample bottle requirements.

A3.2 WELL DRILLING AND DESIGN

Well drilling and construction will comply with requirements defined in WAC 173-160, "Minimum Standards for Construction and Maintenance of Wells." The boreholes will be drilled so they can be constructed as groundwater monitoring wells for the 200-BP-5 Groundwater OU. The wells addressed in this SAP are designated either as an unconfined aquifer monitoring well or as a confined aquifer monitoring well. The designation for each well is found in Table A3-1.

Table A3-1. Monitoring Well Aquifer.

Borehole/Well Designation	Unconfined Aquifer	Confined Aquifer
"A"	X	
"B"	X	
"C"	X	
"D"	X	
"E"	X	
"F" *		X
"G"		X
"H"		X
"I" *	X	
"J" *	X	
"K"	X	
"L"	X	
"M"	X	
"N"	X	
"O"	X	

*Sampling and analysis requirements for wells "F," "I," and "J" are included in DOE/RL-2006-55, *Sampling and Analysis Plan for FY 2006 200-BP-5 Groundwater Operable Unit Remedial Investigation/Feasibility Study.*

The design proposed for each well is dependent upon whether the well is a confined or unconfined aquifer well. For the unconfined aquifer monitoring wells, the borehole shall be drilled at least 3 ft into the uppermost basalt unit (Elephant Mountain Member). The proposed design for the unconfined monitoring wells is shown in Figure A3-1. The actual well construction design will be finalized by the FH Soil & Groundwater Remediation Project task lead, depending on the observed hydrogeologic conditions and sample analysis results.

For confined aquifer (Rattlesnake Ridge interbed) monitoring wells, the drilling contractor will drill and case the borehole 5 ft into the uppermost basalt surface (Elephant Mountain Member) and then grout and reduce the casing size (i.e., telescope the casing) to properly seal the unconfined aquifer from the deeper Rattlesnake Ridge interbed confined aquifer. All temporary casing shall be removed from the borehole during well completion so annular completion materials can be placed from the surface to the bottom of the borehole. The proposed design for the confined aquifer monitoring wells is shown in Figure A3-2. The final well design (i.e., screen interval) will be selected according to the following major criteria (listed in descending order of importance):

1. Analytical results: Analytical results from depth-discrete sediment and groundwater samples will be evaluated and the screened interval will be placed adjacent to the zone exhibiting the highest concentrations of COPCs. If no contamination is detected, then criterion 2 will be used.

2. Uppermost high-permeability zone: The screened interval will be placed adjacent to the uppermost high-permeability zone to monitor the zone most likely to be affected by contaminant migration.

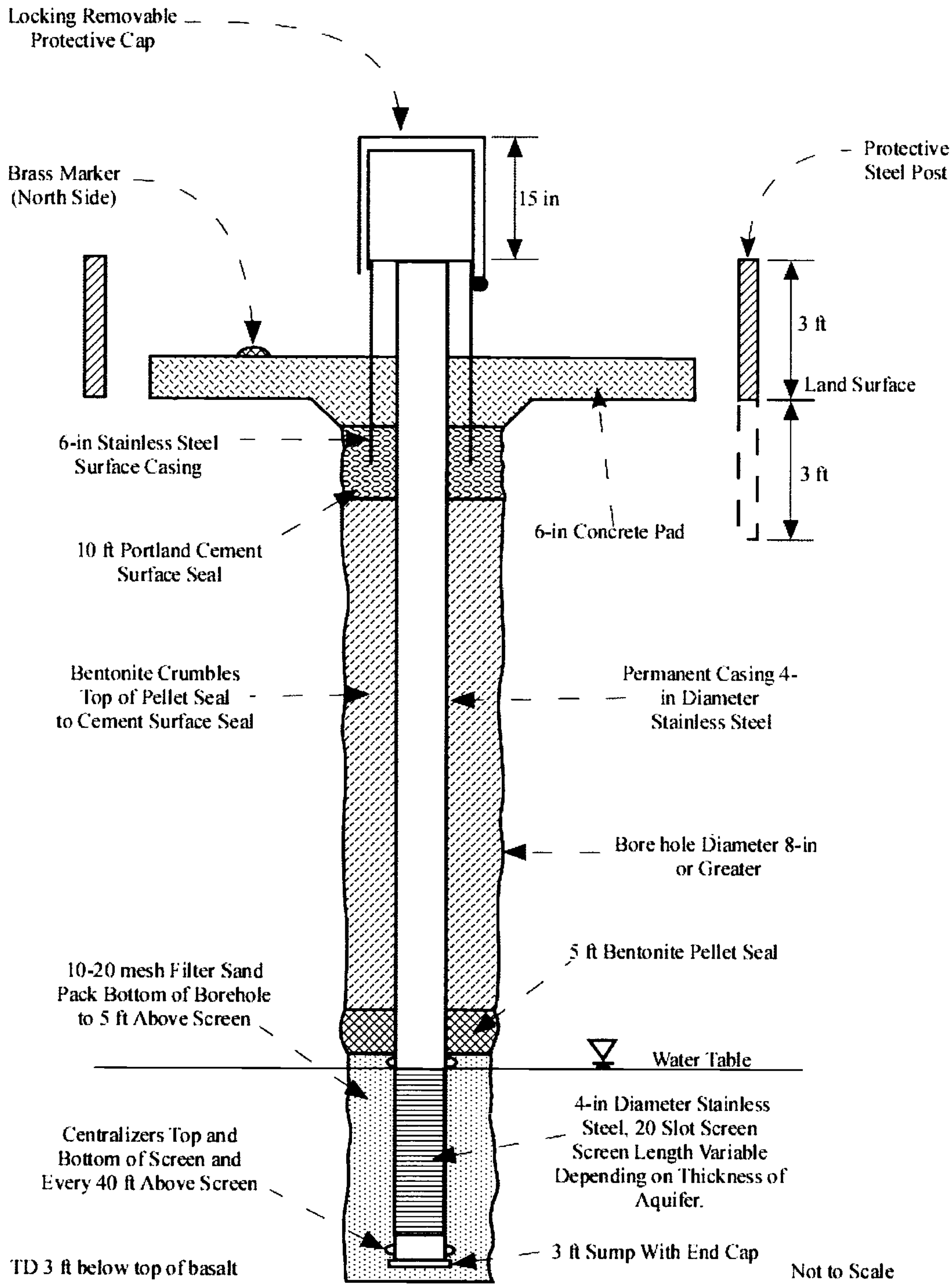
A3.3 SAMPLING LOCATIONS AND FREQUENCY

Figure A1-1 shows the location of the 15 proposed new groundwater wells associated with the 200-BP-5 Groundwater OU RI/FS. Borehole sample collection shall be guided by the sampling scheme illustrated in Figures A3-3 through A3-14 and as summarized in Tables A3-2 through A3-13. Sample collection will be conducted in accordance with FH procedures. In general, sediment samples will be collected using standard grab or split-spoon methods. The sample collection process is designed for comprehensive study of the unsaturated and saturated zone. The number of soil samples collected from borings "A" through "O" typically is considerably greater than the number of samples planned for analysis. The sample collection process is designed for a comprehensive study of the unsaturated and saturated zone. Only a subset of the samples collected will be analyzed. The determination of which samples will be analyzed will be based on sample recovery, sediment type, radiological and vapor field-screening results, borehole geophysics profiles, and preliminary contaminant concentrations. Unused samples will be retained for possible future analysis or disposal.

Groundwater samples will be collected using a depth-discrete KABIS[1] sampler or by pumping. Well-specific sampling designs are summarized in Sections A3.3.1 through A3.3.12. General sampling requirements applicable to all of the monitoring well drilling locations (i.e., geophysical logging) are summarized in Section A3.3.13.

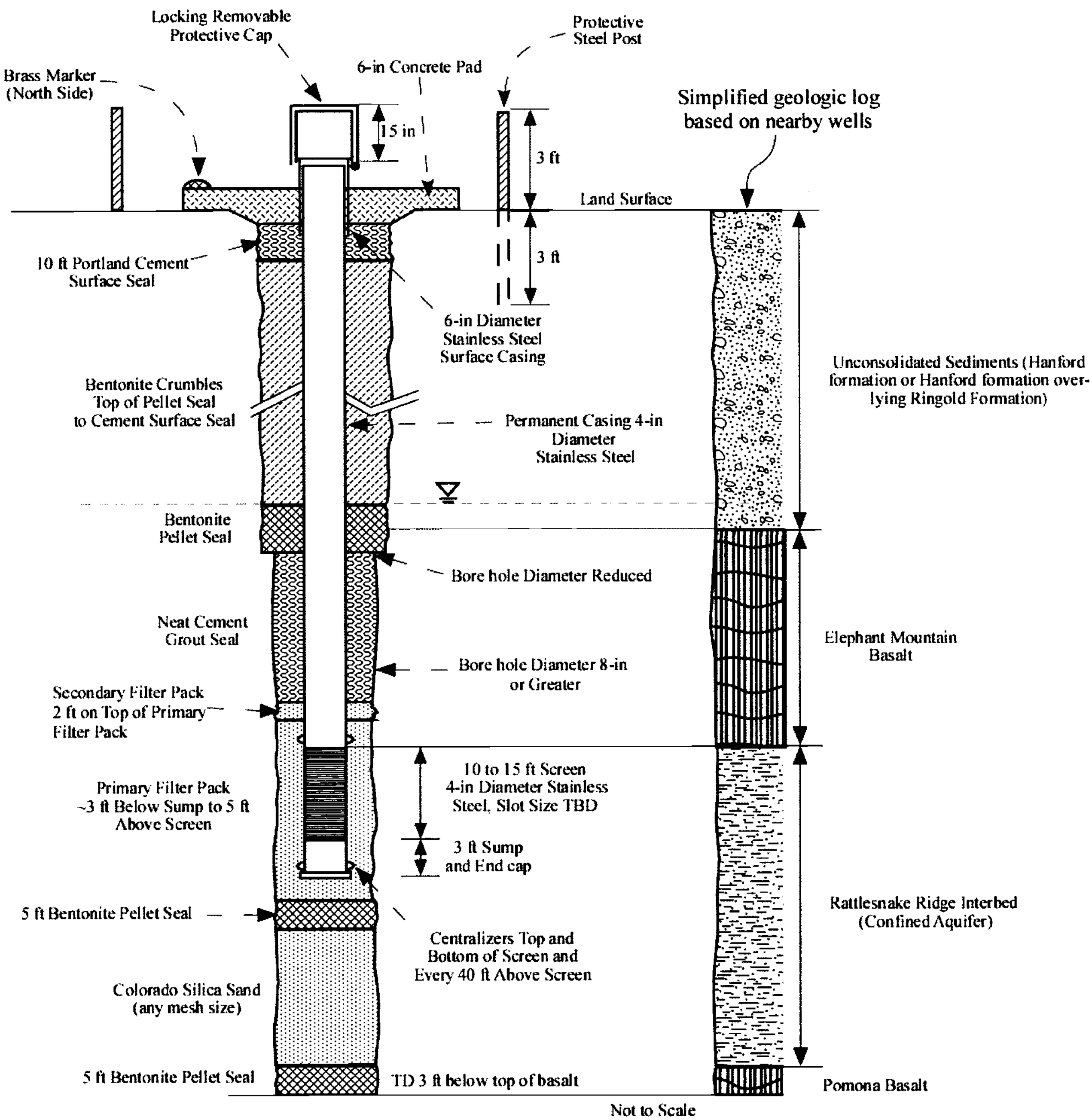
[1] KABIS sampler is a product of Sibak Industries, San Marcos, California.

Figure A3-1. Proposed Design for Unconfined Aquifer Monitoring Wells.



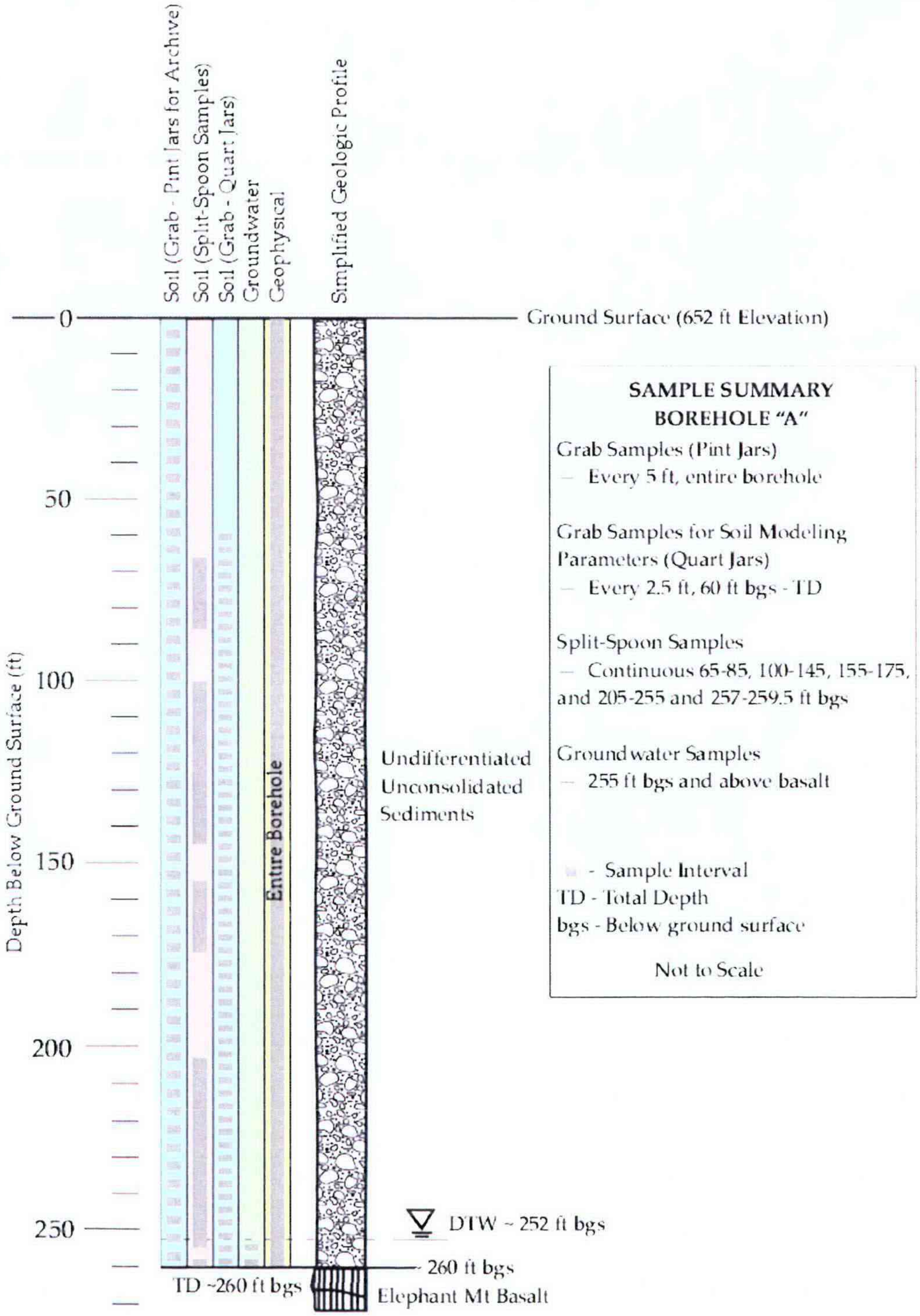
TD = total depth.

Figure A3-2. Proposed Design and Expected Geology for Confined Aquifer Monitoring Wells.



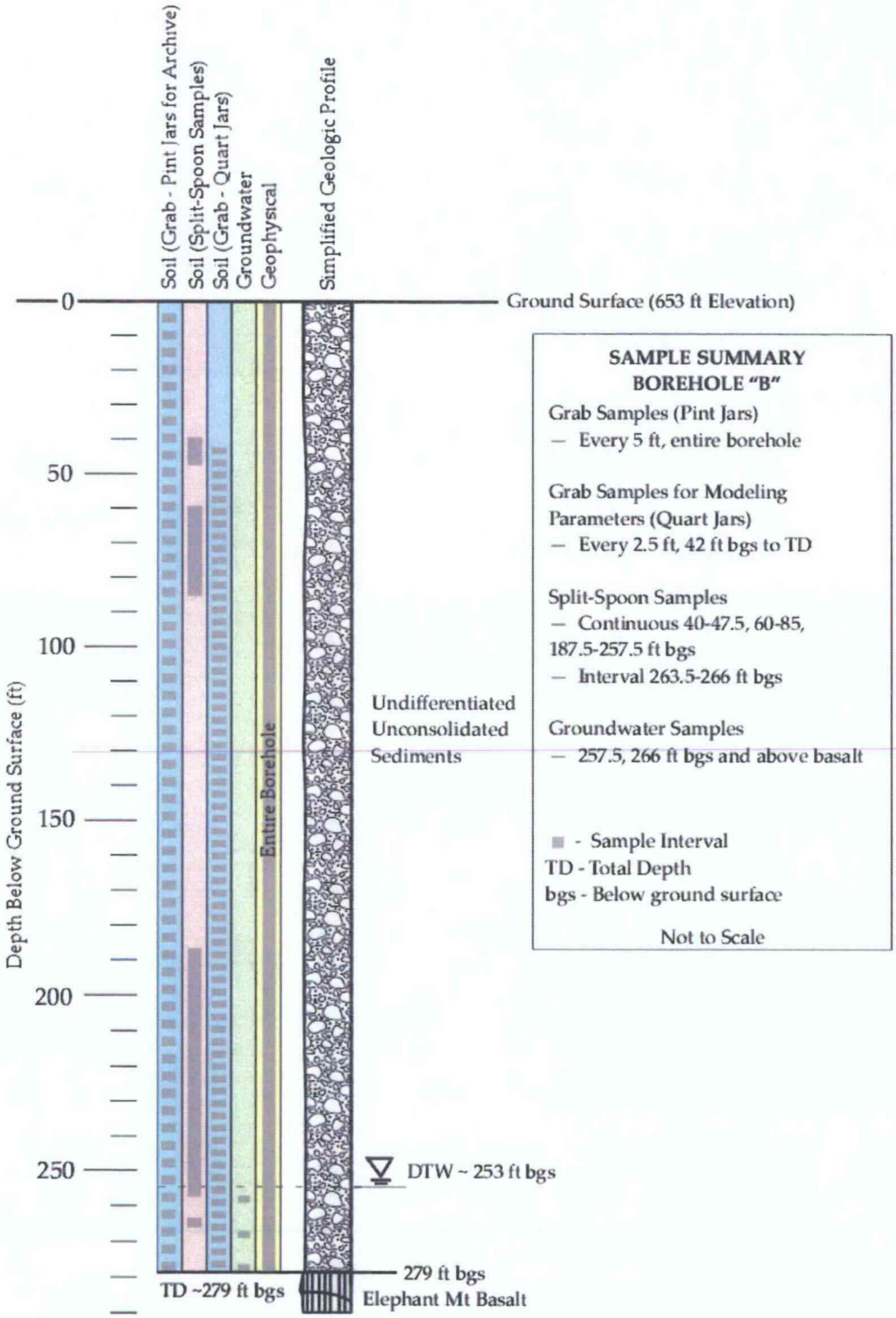
TBD = to be determined.
TD = total depth.

Figure A3-3. Borehole Sampling Scheme for Well "A."



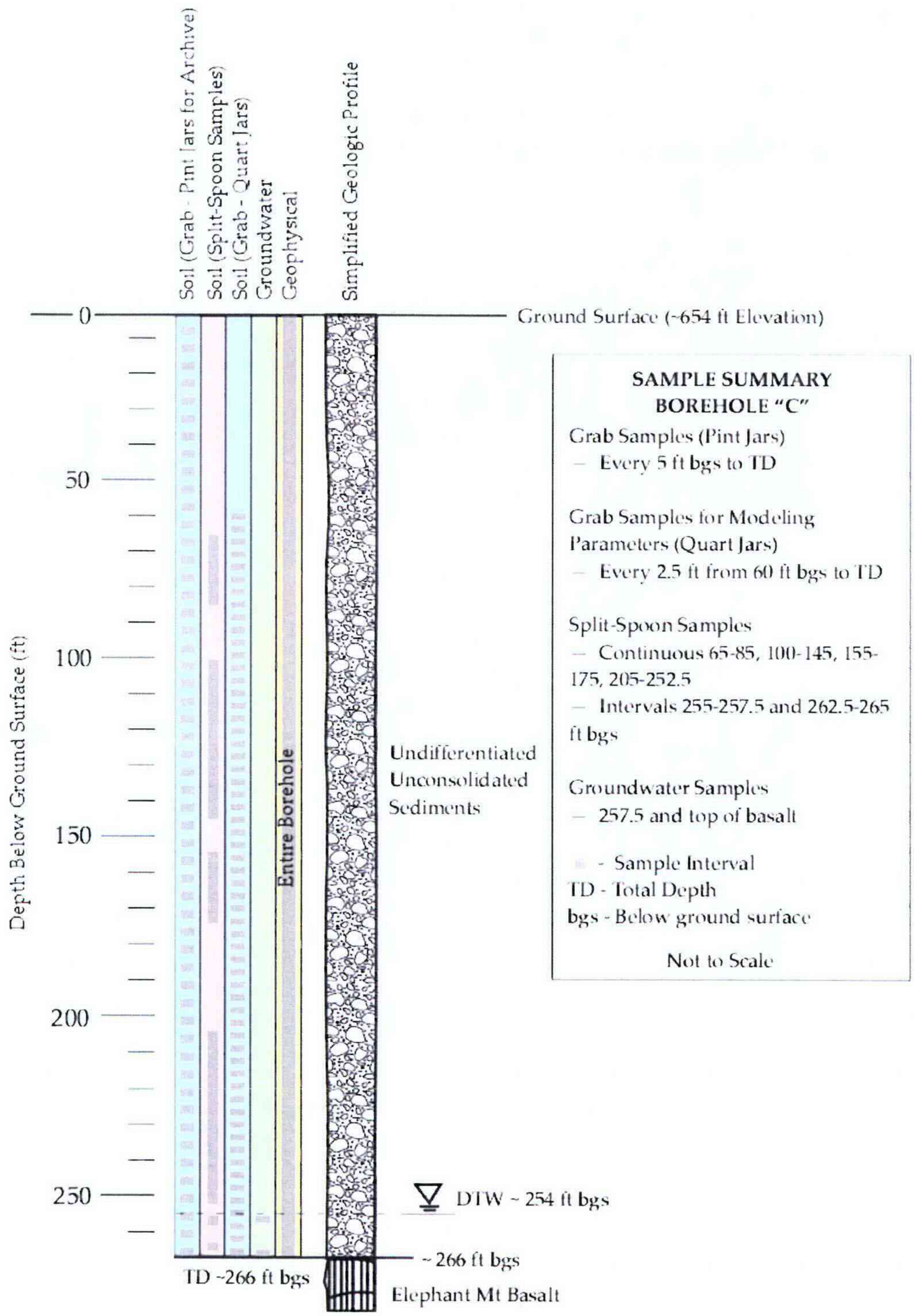
DTW = depth to groundwater.

Figure A3-4. Borehole Sampling Scheme for Well "B."



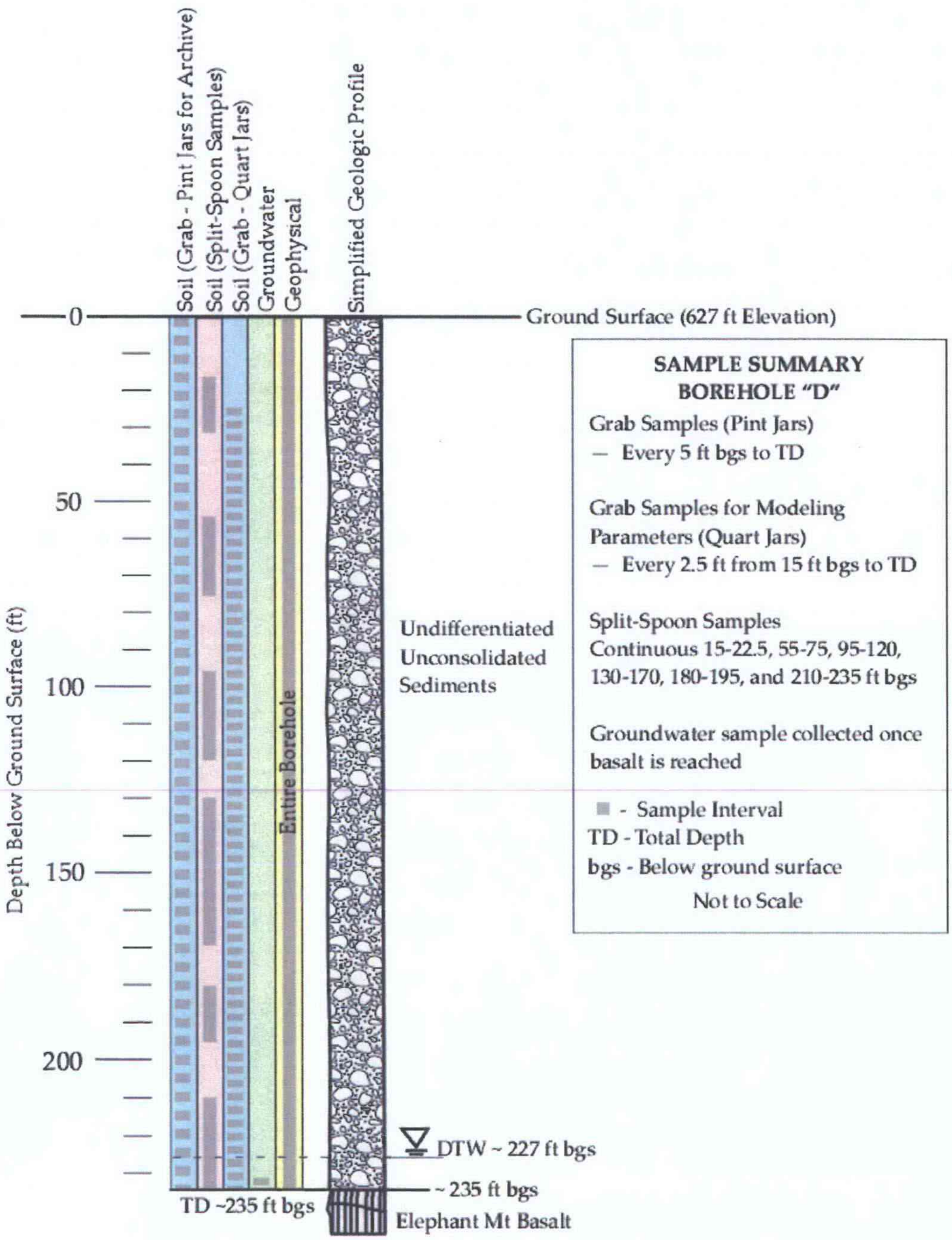
DTW = depth to groundwater.

Figure A3-5. Borehole Sampling Scheme for Well "C."



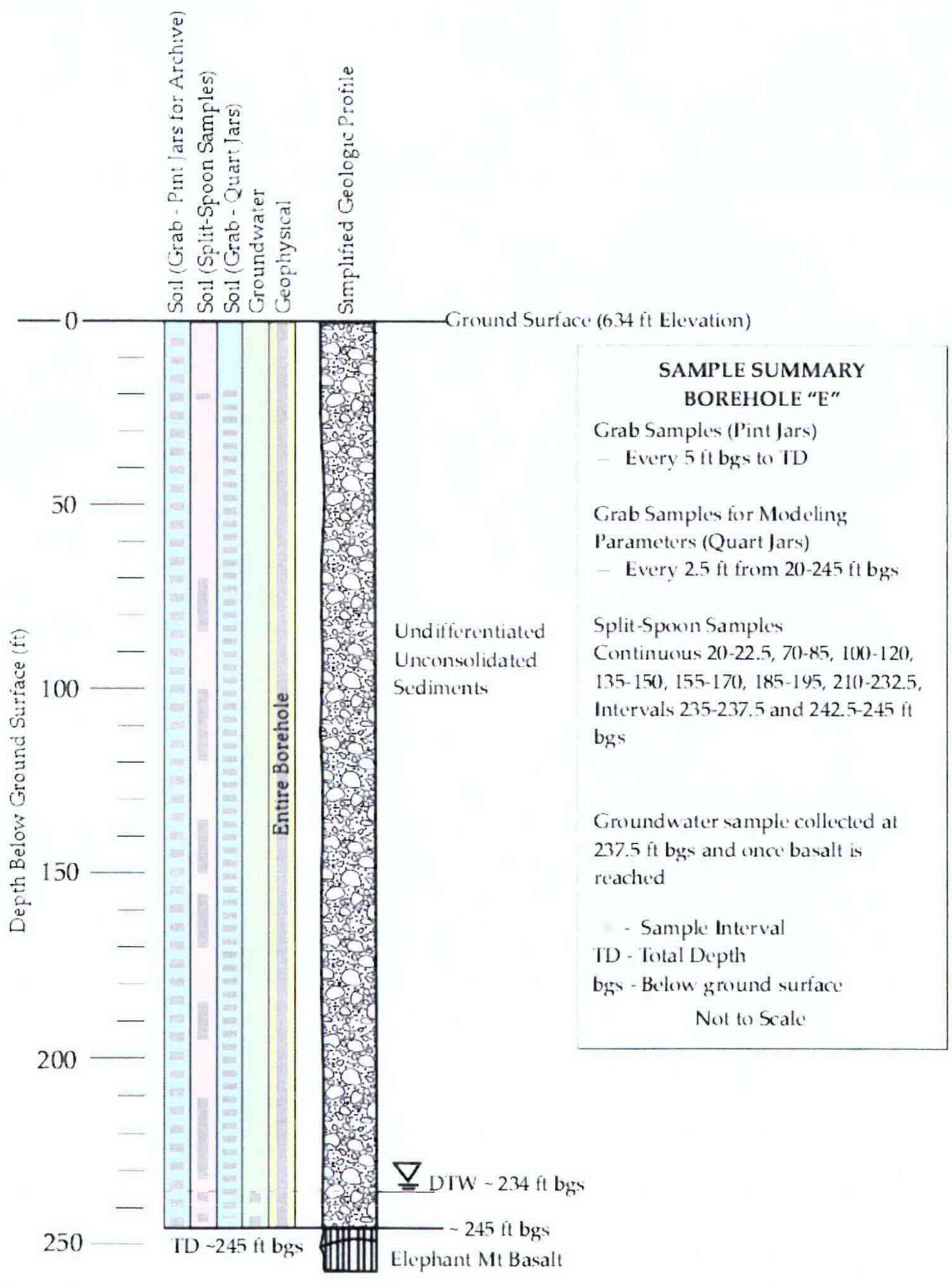
DTW = depth to groundwater.

Figure A3-6. Borehole Sampling Scheme for Well "D."



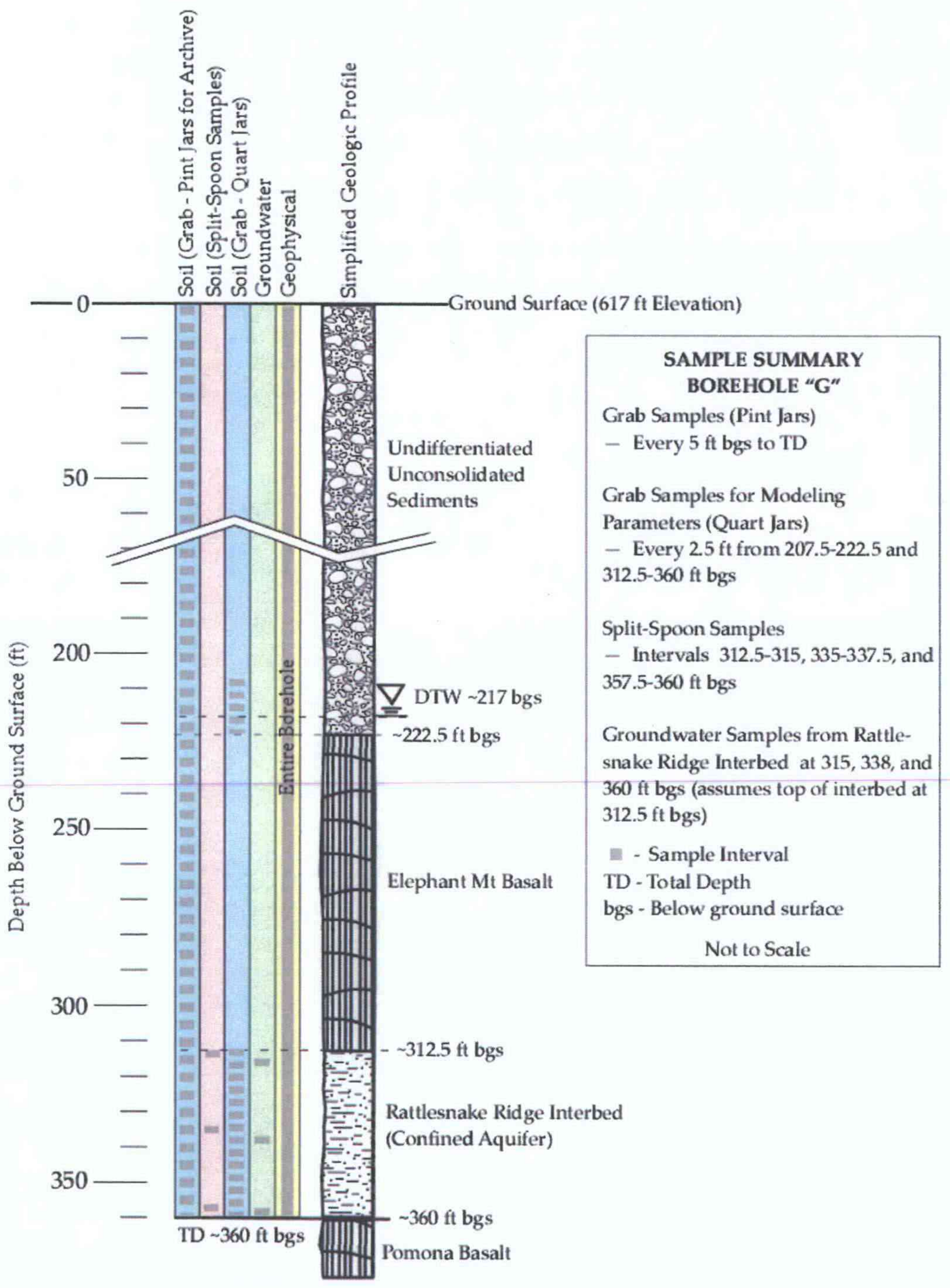
DTW = depth to groundwater.

Figure A3-7. Borehole Sampling Scheme for Well "E."



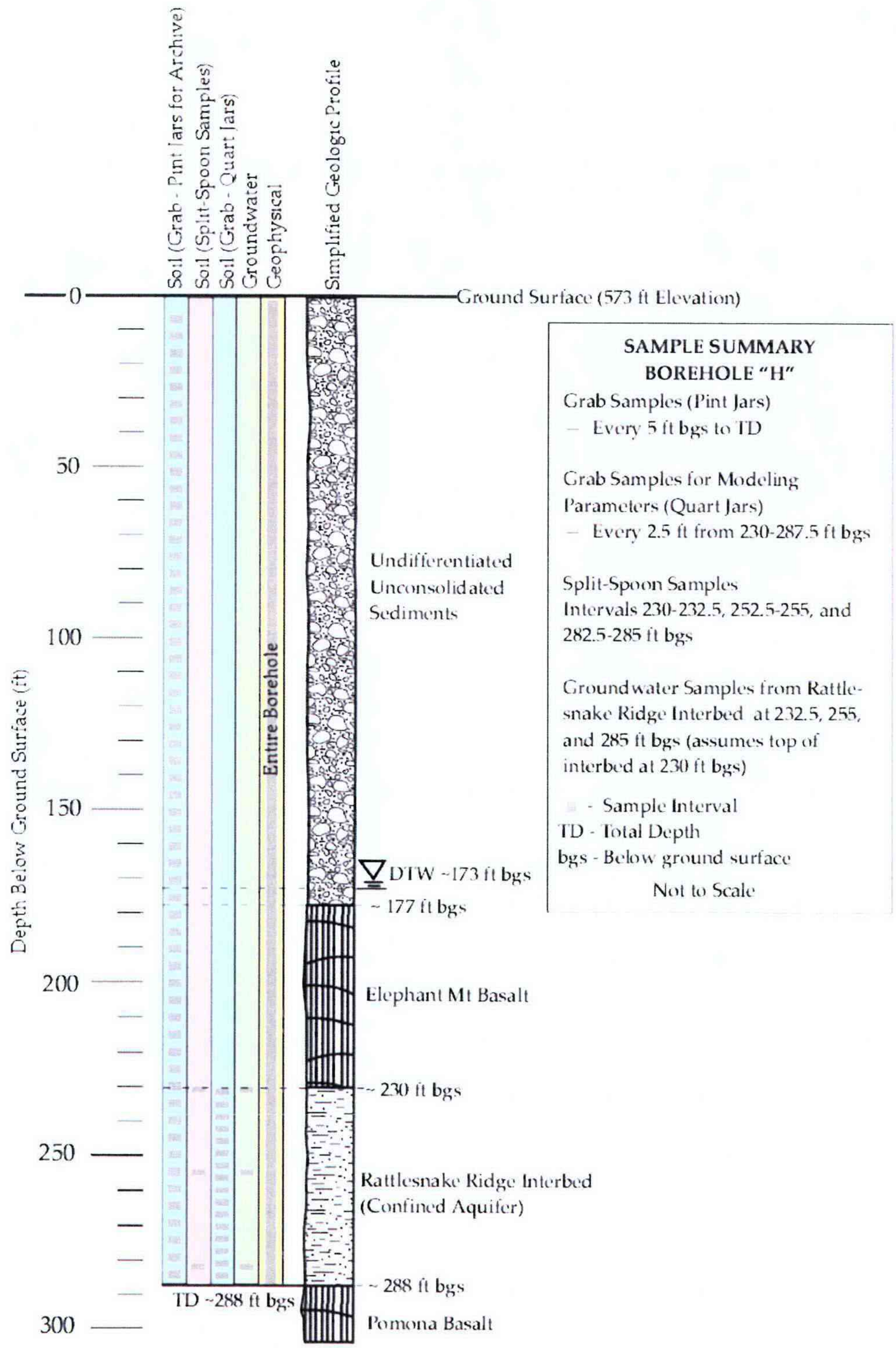
DTW = depth to groundwater.

Figure A3-8. Borehole Sampling Scheme for Well "G."



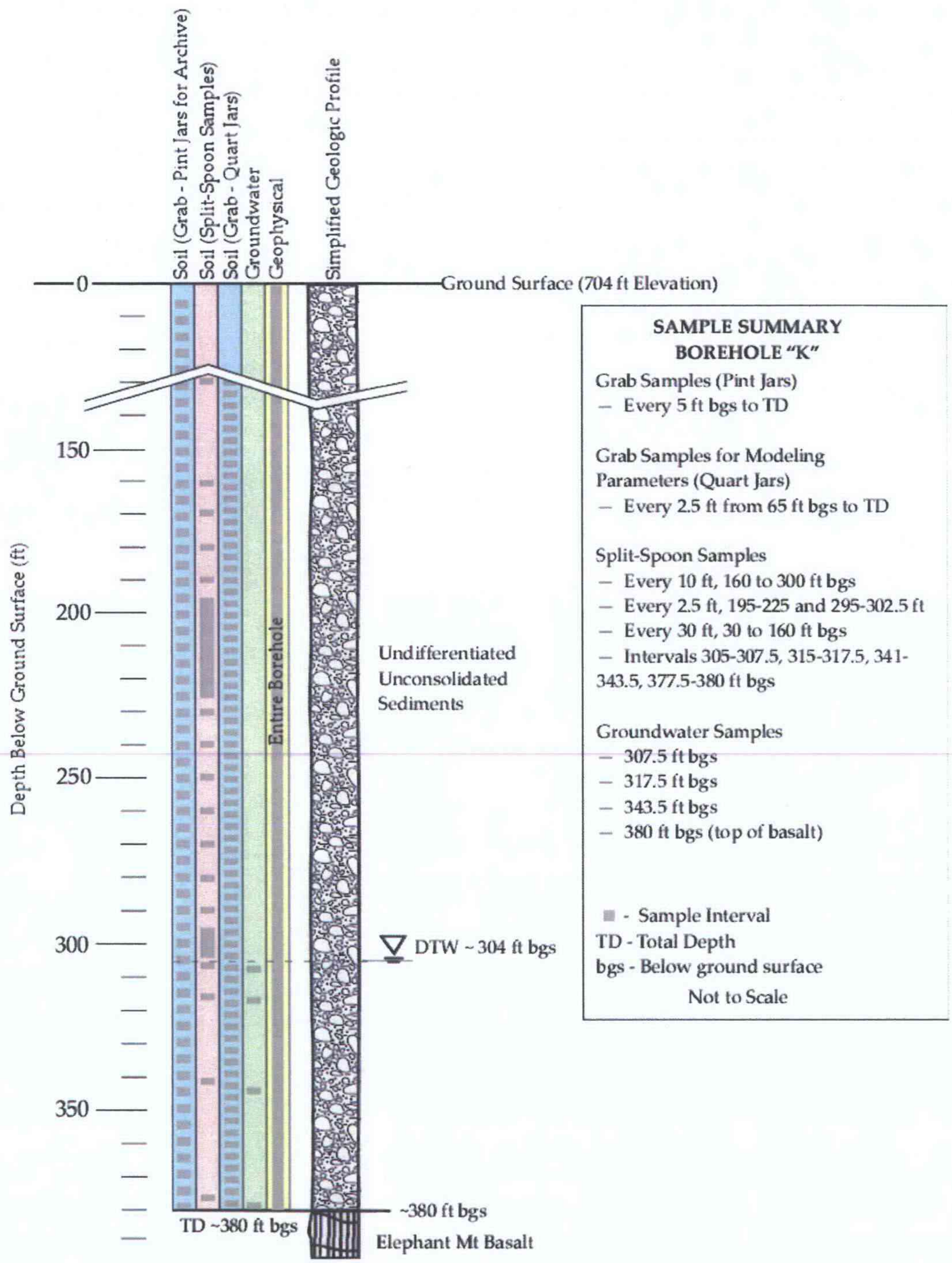
DTW = depth to groundwater.

Figure A3-9. Borehole Sampling Scheme for Well "H."



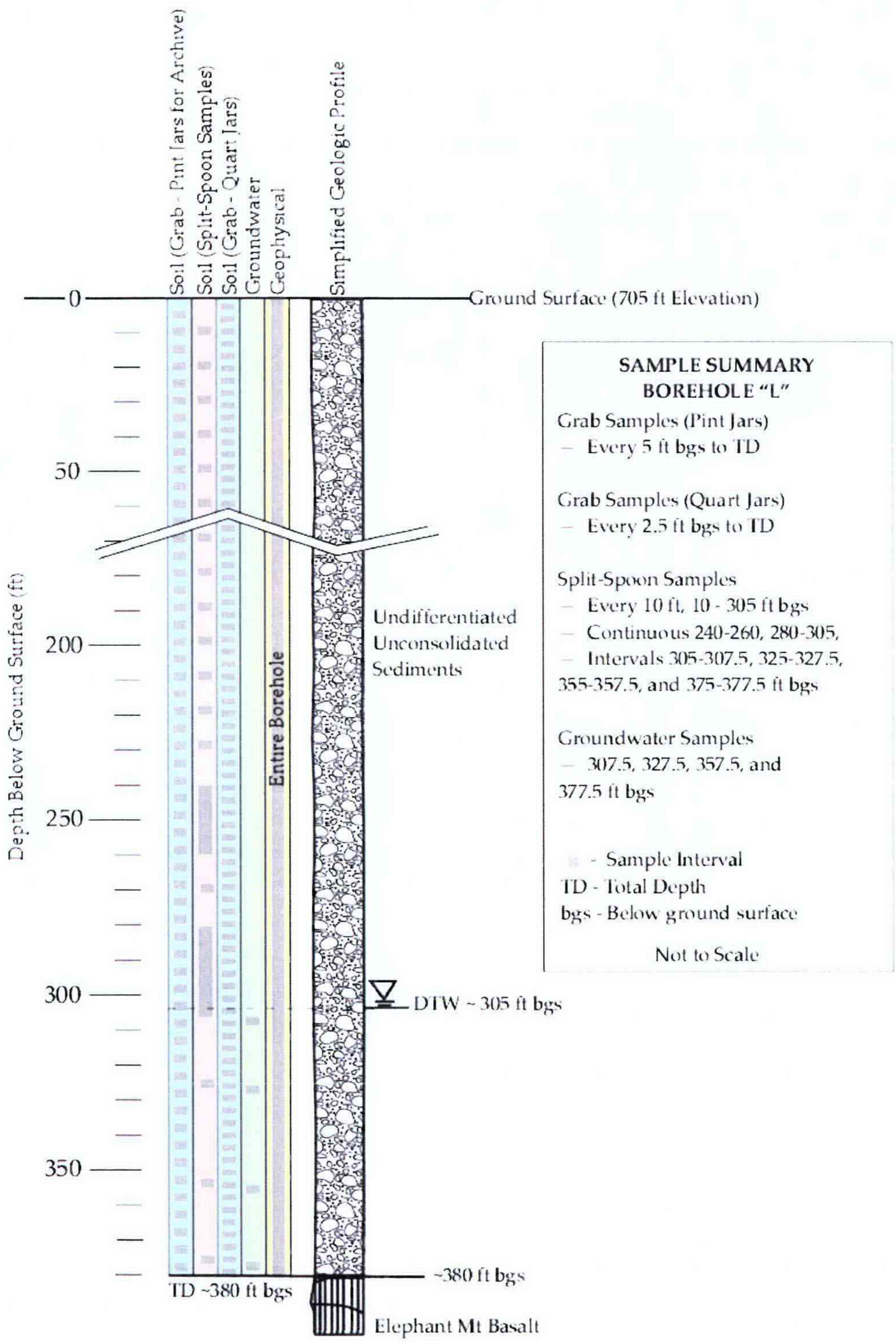
DTW = depth to groundwater.

Figure A3-10. Borehole Sampling Scheme for Well "K."



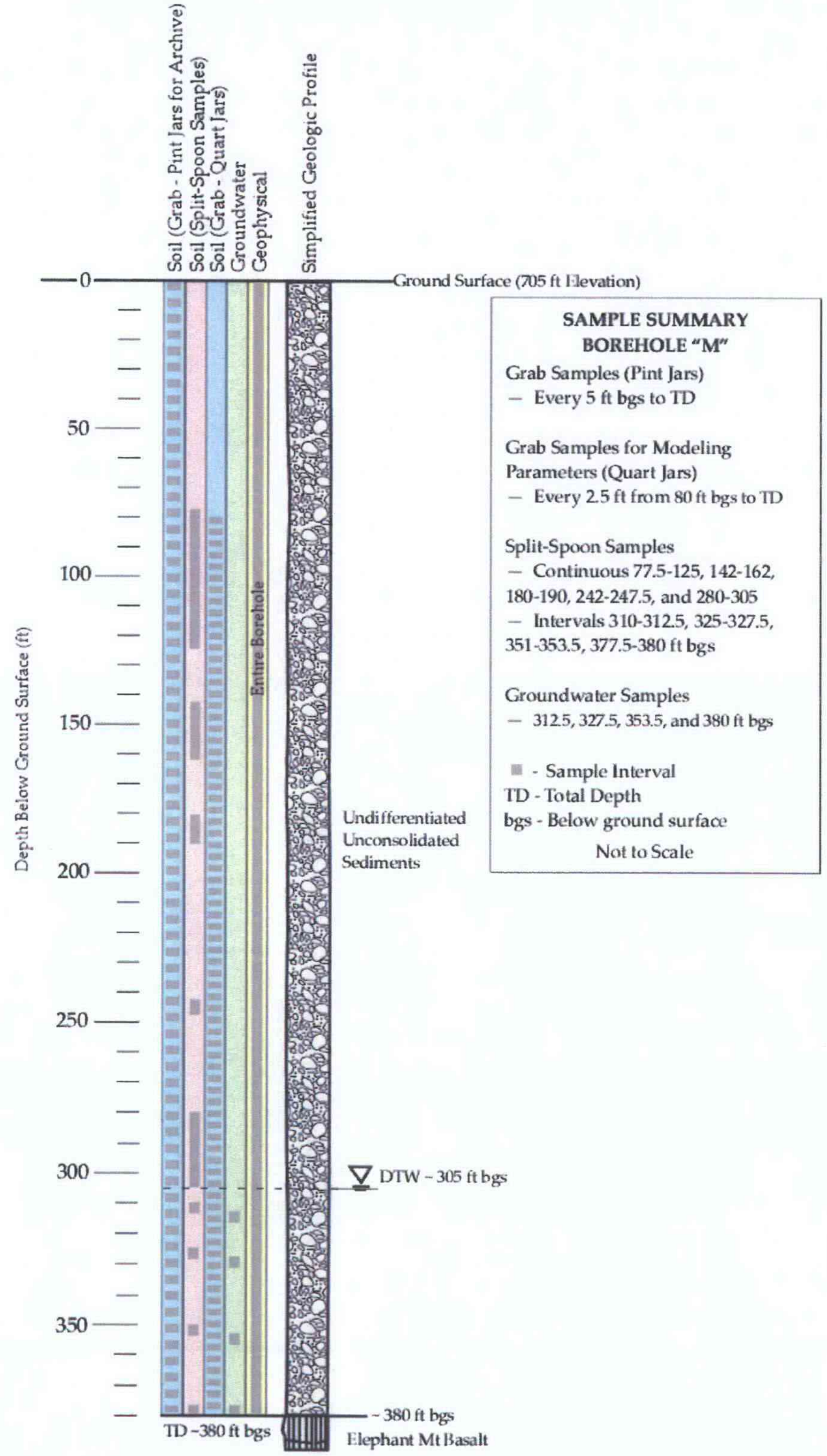
DTW = depth to groundwater.

Figure A3-11. Borehole Sampling Scheme for Well "L."



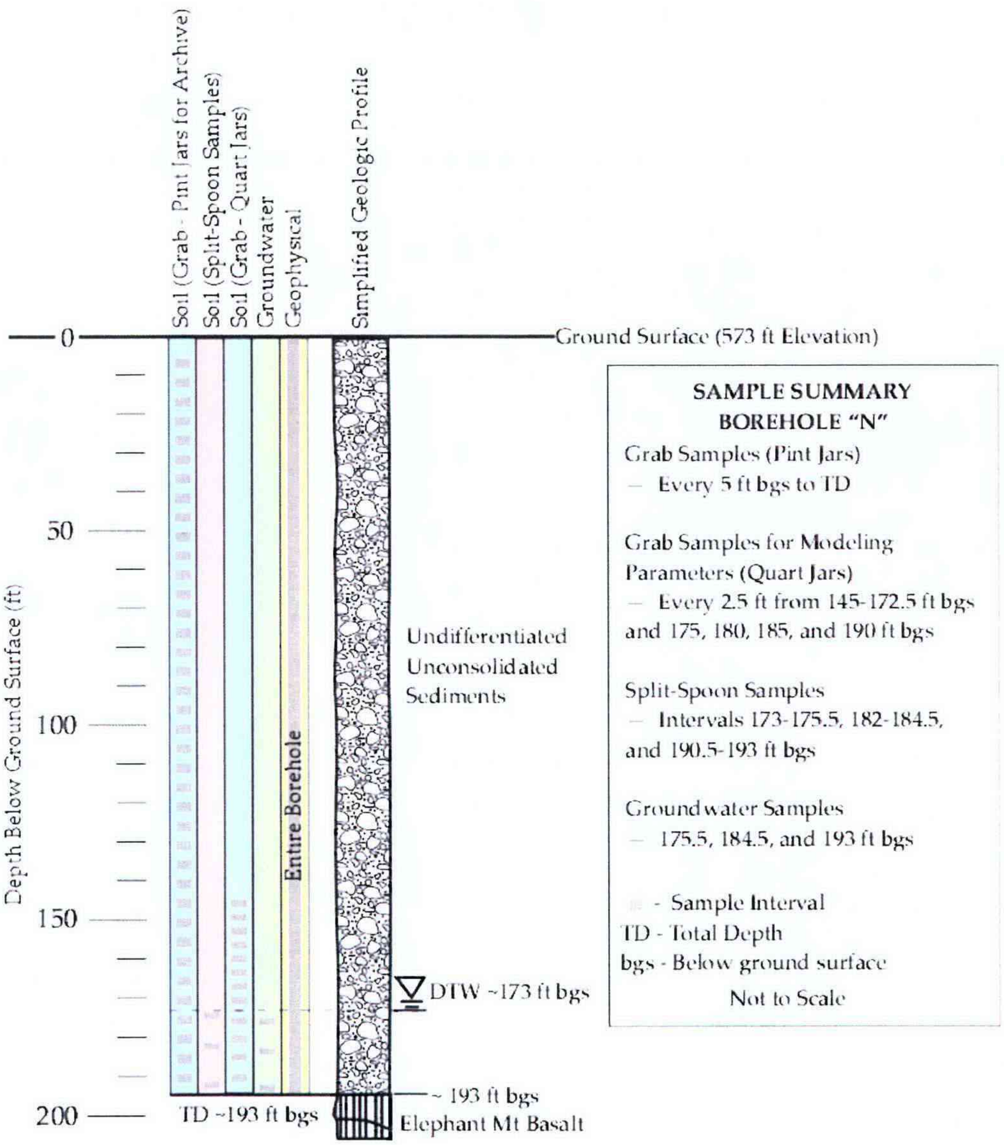
DTW = depth to groundwater.

Figure A3-12. Borehole Sampling Scheme for Well "M."



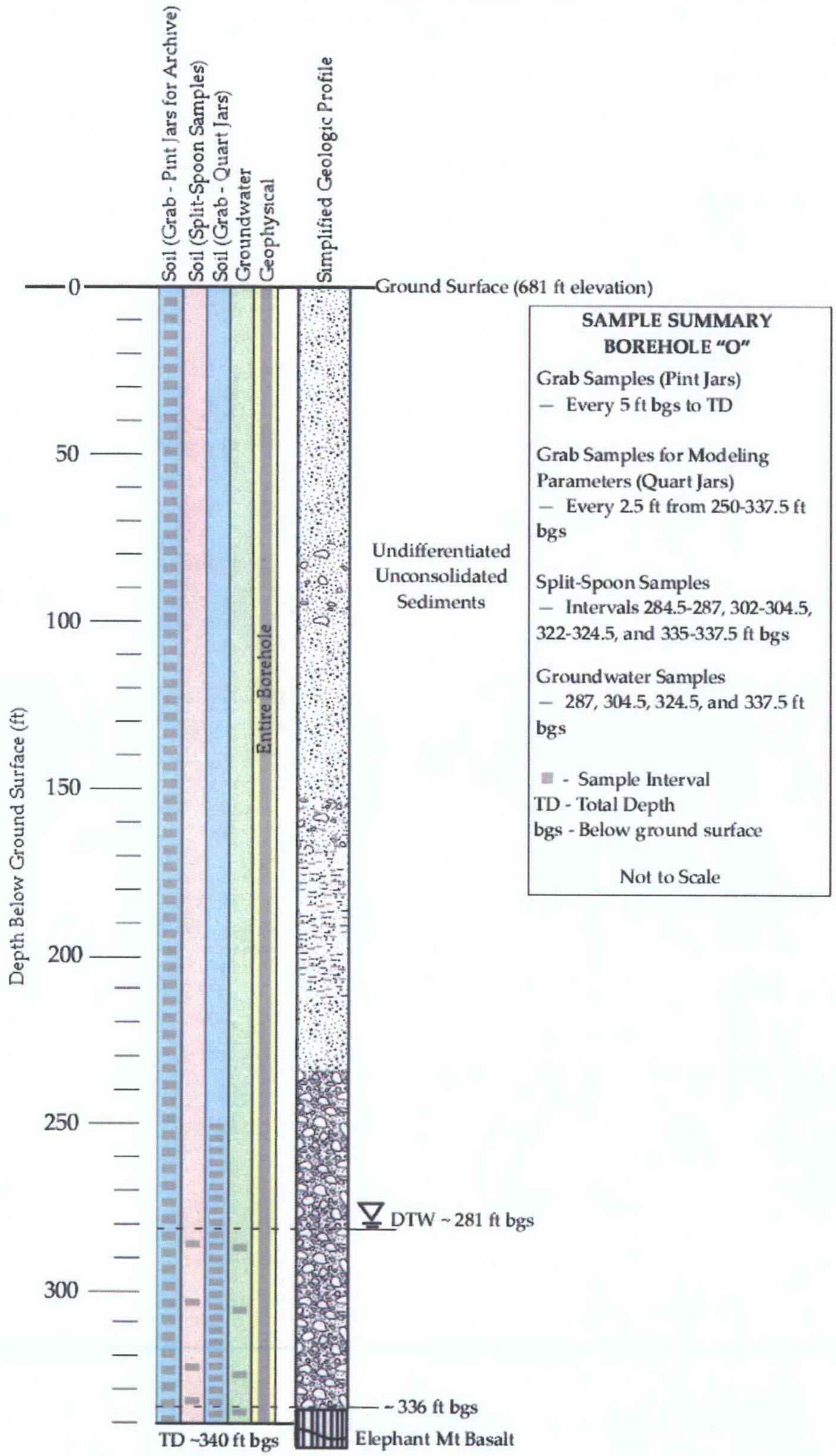
DTW = depth to groundwater.

Figure A3-13. Borehole Sampling Scheme for Well "N."



DTW = depth to groundwater.

Figure A3-14. Borehole Sampling Scheme for Well "O."



DTW = depth to groundwater.

Table A3-2. Sediment and Groundwater Samples for Borehole "A." (2 Pages)

Sample Location	Sample Collection Method	Sample Collection Interval	Number of Samples Collected (Number of Samples Analyzed)*	Sample Destination/ Analyte List
Lithologic Archive Samples				
Borehole A	Grab pint jar	Every 5 ft and at major changes in lithology.	52 samples, based on estimated depth (0 for analysis).	Sample archive storage building/no analysis required.
Vadose-Zone Sediment Samples				
Borehole "A"	Split-spoon	Split-spoon samples collected every 2.5 ft over intervals (ft bgs): 65 to 85, 100 to 145, 155 to 175, and 205 to 252.5.	53 samples (up to 8 for analysis by PNNL).	PNNL/Up to eight samples will be analyzed for several physical parameters (Table A1-12) including particle-size distribution, lithology, and bulk density.
Borehole "A"	Split-spoon	Samples taken from split-spoons from 224.5- to 227-ft, 235.5- to 238-ft, and 247.5- to 250-ft intervals. Intervals are preliminary and may change based on field-screening results.	Three samples (three for analysis). One duplicate sample.	WSCF/Three vadose-zone sediments and one duplicate will be analyzed for COPC listed in Tables A1-6 and A1-7.
Borehole "A"	Grab quart jar	Grab samples collected every 2.5 ft over the interval (ft bgs): 60 to 252.5. Samples collected at every 10-ft interval will be analyzed.	78 samples (20+ for analysis) Additional analysis may be completed based on initial results and additional intervals may be analyzed as needed.	PNNL/Model development parameters (Table A1-12) will be analyzed as well as some hydraulic and transport parameters including moisture, cation-exchange capacity, uranium isotopic signature analyses, and cyanide extraction and analysis. Unused samples to be retained by PNNL for possible future analyses or disposal.
Saturated Zone Sediment Samples				
Borehole "A"	Split-spoon	Split-spoon samples will be collected over the intervals (ft bgs): 252.5 to 255 and 257 to 259.5 (estimated water table contact at 252 ft bgs).	Two samples (one sample for analysis by PNNL, one sample for analysis by WSCF at water table).	PNNL/One sample will be analyzed for some physical parameters (Table A1-12) including particle size distribution, lithology, and bulk density. WSCF/One saturated zone sediment anlysis will be analyzed for COPCs listed in Tables A1-8 and A1-9.
Borehole "A"	Grab quart jar	Grab samples collected every 2.5 ft over the interval (ft bgs): 252.5 to 260. The samples from intervals 252.5 and 257.5 are proposed for PNNL analysis.	Four samples (two for analysis).	PNNL/Model development parameters (Table A1-12) will be analyzed as well as some hydraulic and transport parameters including cation-exchange capacity, uranium isotopic signature analyses, distribution coefficient, TOC, and TIC. Unused samples to be retained by PNNL for possible future analyses or disposal.
Groundwater Samples				
Borehole "A"	Pump or KABIS	Sample collected at interval (ft bgs): 255 (estimated water table contact at 252 ft bgs).	One sample (one for analysis).	PNNL/Uranium isotopic signature estimate (Table A1-12).
Borehole "A"	Pump or KABIS	Sample collected at interval (ft bgs): 257 to 259.5.	One sample (one for analysis). One duplicate.	WSCF/One groundwater sample for COPCs listed in Tables A1-10 and A1-11.

Table A3-2. Sediment and Groundwater Samples for Borehole "A." (2 Pages)

Sample Location	Sample Collection Method	Sample Collection Interval	Number of Samples Collected (Number of Samples Analyzed)*	Sample Destination/ Analyte List
Estimated land surface elevation (ft amsl)				652
Estimated depth to groundwater (ft bgs)				252
Estimated depth to basalt (ft bgs)				260
Estimated maximum depth of investigation (ft bgs)				260
Maximum number of samples to collect (not including pint archive samples)				144
Number of samples for laboratory analysis*				30+
Approximate number of field quality control samples (five field blanks, two equipment blanks)				7

*The sample collection process is designed for comprehensive study of the unsaturated and saturated zone. As noted, only a subset of these samples will be analyzed. The determination of which samples will be analyzed will be based on sample recovery, sediment type, radiological and vapor field-screening results, borehole geophysics profiles, and preliminary contaminant concentrations.

KABIS sampler is a product of Sibak Industries, San Marcos, California.

amsl = above mean sea level.
bgs = below ground surface.
COPC = contaminant of potential concern.
PNNL = Pacific Northwest National Laboratory.
TIC = tentatively identified compound.
TOC = total organic carbon.
WSCF = Waste Sampling and Characterization Facility.

Table A3-3. Sediment and Groundwater Samples for Borehole "B." (2 Pages)

Sample Location	Sample Collection Method	Sample Collection Interval	Number of Samples Collected (Number of Samples Analyzed)*	Sample Destination/ Analyte List
Lithologic Archive Samples				
Borehole "B"	Grab pint jar	Every 5 ft and at major changes in lithology.	56 samples (based on estimated depth).	Sample archive storage building/no analysis required.
Vadose-Zone Sediment Samples				
Borehole "B"	Split-spoon	Split-spoon samples collected every 2.5 ft over intervals (ft bgs): 40 to 47.5, 60 to 85, 187.5 to 252.5. Two sample intervals are planned to be analyzed based on soil recovery, soil type, and preliminary contaminant concentrations.	41 samples (2 for analysis by PNNL).	PNNL/Two samples will be anlyzed for several physical parameters (Table A1-12) including particle-size distribution, lithology, and bulk density.
Borehole "B"	Split-spoon	Collected from three split-spoon samples from the intervals (ft bgs): 72.5 to 75, 200 to 202.5, and 235 to 237.5.	Four samples (three samples for analysis and one duplicate sample).	WSCF/Three vadose-zone samples analyzed for COPCs listed in Tables A1-6 and A1-7.
Borehole "B"	Grab quart jar	Grab samples collected every 2.5 ft between interval 42 to 252.5 ft bgs. Samples collected every 10-ft interval will be analyzed.	84 samples (26+ for analysis – one every 10 ft between 42 and 232 ft bgs, and one every 2.5 ft between 235 ft and 252.5 ft bgs) Additional analysis may be completed based on initial results and additional intervals may be analyzed as needed.	PNNL/Model development parameters (Table A1-12) will be analyzed as well as some hydraulic and transport parameters including moisture, cation-exchange capacity, uranium isotopic signature analyses, and cyanide extraction and analysis. Unused samples to be retained by PNNL for possible future analyses or disposal.
Saturated Zone Sediment Samples				
Borehole "B"	Split-spoon	Two split-spoons will be collected over the intervals 255 to 257.5 and 263.5 to 266 ft bgs (estimated water table contact at 253 ft bgs).	Five samples (two samples for analysis by PNNL, two samples for analysis by WSCF, and one duplicate analysis by WSCF).	PNNL/Two samples will be analyzed for some physical parameters (Table A1-12) including particle density. Also, some hydraulic and transport parameters will be analyzed including particle-size distribution; cation-exchange capacity; distribution coefficient for uranium and Tc-99; TOC; TIC; and moisture. WSCF/Two saturated zone sediments and one duplicate sample will be analyzed for COPCs listed in Tables A1-8 and A1-9.

Table A3-3. Sediment and Groundwater Samples for Borehole "B." (2 Pages)

Sample Location	Sample Collection Method	Sample Collection Interval	Number of Samples Collected (Number of Samples Analyzed)*	Sample Destination/ Analyte List
Borehole "B"	Grab quart jar	Grab samples collected every 2.5 ft between interval 255 to the bottom of the borehole.	11 samples (3 for analysis from the grab sample depths of 255 ft, 265 ft, and 273 ft bgs).	PNNL/Three sediment samples will be analyzed for model development parameters (Table A1-12) as well as some hydraulic and transport parameters including cation-exchange capacity, uranium isotopic signature analyses, distribution coefficient, TOC, and TIC. Unused samples to be retained by PNNL for possible future analyses or disposal.
Groundwater Samples				
Borehole "B"	Pump or KABIS	Sample collected at interval (ft bgs): 257.5 and at the top of basalt.	Two samples (two samples).	PNNL/Analyzed for uranium isotopic signature estimate (Table A1-12).
Borehole "B"	Pump or KABIS	Samples will be collected at intervals (ft bgs): 266 and top of basalt.	Three samples (two samples to be analyzed by WSCF and one duplicate).	WSCF/Two groundwater samples and one duplicate will be analyzed for COPCs listed in Tables A1-10 and A1-11.
Estimated land surface elevation (ft amsl)				653
Estimated depth to groundwater (ft bgs)				253
Estimated depth to basalt (ft bgs)				279
Estimated maximum depth of investigation (ft bgs)				279
Maximum number of samples to collect (not including pint archive samples)				150
Number of samples for laboratory analysis*				45+
Approximate number of field quality control samples (five field blanks, two equipment blanks)				7

*The sample collection process is designed for comprehensive study of the unsaturated and saturated zone. As noted, only a subset of these samples will be analyzed. The determination of which samples will be analyzed will be based on sample recovery, sediment type, radiological and vapor field-screening results, borehole geophysics profiles, and preliminary contaminant concentrations.

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TOC = total organic carbon.
WSCF = Waste Sampling and Characterization Facility.

Table A3-4. Sediment and Groundwater Samples for Borehole "C." (2 Pages)

Sample Location	Sample Collection Method	Sample Collection Interval	Number of Samples Collected (Number of Samples Analyzed)*	Sample Destination/ Analyte List
Lithologic Archive Samples				
Borehole "C"	Grab pint jar	Every 5 ft and at major changes in lithology.	52 samples, based on estimated depth (0 for analysis).	Sample archive storage building/no analysis required.
Unsaturated Zone Sediment Samples				
Borehole "C"	Split-spoon	Split-spoon samples collected every 2.5 ft over intervals (ft bgs): 65 to 85, 100 to 145, 155 to 175, and 205 to 252.5.	57 samples (up to 8 for analysis).	PNNL/Up to 11 samples will be analyzed for several physical parameters (Table A1-12) including particle-size distribution, lithology, and bulk density.
Borehole "C"	Split-spoon	Split-spoon samples collected from intervals (ft bgs): 160 to 162.5, 217.5 to 220, and 230 to 232.5.	Four samples (three samples for analysis and one duplicate sample for analysis).	WSCF/Three vadose-zone samples analyzed for COPCs listed in Tables A1-6 and A1-7.
Borehole "C"	Grab quart jar	Grab samples collected every 2.5 ft over the interval (ft bgs): 60 to 252.5. Samples collected at every 10-ft interval will be analyzed. Additional analysis may be completed based on initial results and additional intervals may be analyzed as needed.	82 samples (20+ for analysis). Samples collected at every 10-ft interval will be analyzed. Additional analysis may be completed based on initial results and additional intervals may be analyzed as needed.	PNNL/Model development parameters (Table A1-12) will be analyzed as well as some hydraulic and transport parameters including moisture, cation-exchange capacity, uranium isotopic signature analyses, and cyanide extraction and analysis. Unused samples to be retained by PNNL for possible future analyses or disposal.
Saturated Zone Sediment Samples				
Borehole "C"	Split-spoon	Two split-spoon samples will be collected over intervals (ft bgs): 255 to 257.5 and 262.5 to 265 (estimated water table contact at 254 ft bgs).	Four samples (possibly one sample for analysis by PNNL; two samples and one duplicate for analysis by WSCF).	PNNL/Possibly one sample will be analyzed for some physical parameters (Table A1-12) including particle size distribution, lithology, and bulk density WSCF/Two saturated zone sediment samples and one duplicate sample will be analyzed for the COPCs listed in Tables A1-8 and A1-9.
Borehole C	Grab Quart Jar	Grab samples collected every 2.5 ft over the interval (ft bgs): 255 to 265 (assuming water table contact at 254 ft bgs).	Five samples (two for analysis).	PNNL/Two sediment samples will be analyzed for model development parameters (Table A1-12) as well as some hydraulic and transport parameters including cation-exchange capacity, uranium isotopic signature analyses, distribution coefficient, TOC, and TIC. Unused samples to be retained by PNNL for possible future analyses or disposal.

Table A3-4. Sediment and Groundwater Samples for Borehole "C." (2 Pages)

Sample Location	Sample Collection Method	Sample Collection Interval	Number of Samples Collected (Number of Samples Analyzed)*	Sample Destination/ Analyte List
Groundwater Samples				
Borehole C	Pump or KABIS	Two sample intervals will be targeted for collection of groundwater. The intervals are planned from the split-spoon intervals 257.5 and the top of basalt.	Four samples (two samples and one duplicate for analysis by WSCF, and possibly one for isotopic uranium analysis by PNNL).	PNNL/Possibly one uranium isotopic signature, if determined applicable, will be analyzed (Table A1-12). WSCF/Two groundwater sample and duplicate will be analyzed for COPCs listed in Tables A1-10 and A1-11.
Estimated land surface elevation (ft amsl)				654
Estimated depth to groundwater (ft bgs)				254
Estimated depth to basalt (ft bgs)				266
Estimated maximum depth of investigation (ft bgs)				266
Maximum number of collected samples (not including pint archive samples)				156
Number of samples for laboratory analysis*				34+
Approximate number of field quality control samples (seven field blanks, two equipment blanks)				9

*The sample collection process is designed for comprehensive study of the unsaturated and saturated zone. As noted, only a subset of these samples will be analyzed. The determination of which samples will be analyzed will be based on sample recovery, sediment type, radiological and vapor field-screening results, borehole geophysics profiles, and preliminary contaminant concentrations.

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Table A3-5. Sediment and Groundwater Samples for Borehole "D." (3 Pages)

Sample Location	Sample Collection Method	Sample Collection Interval	Number of Samples Collected (Number of Samples Analyzed)[a]	Sample Destination/ Analyte List
Lithologic Archive Samples				
Borehole "D"	Grab pint jar	Every 5 ft and at major changes in lithology.	48 samples, based on estimated depth (0 for analysis).	Sample archive storage building/no analysis required.
Unsaturated Zone Sediment Samples				
Borehole "D"	Split-spoon	Split-spoon samples will be collected continuously every 2.5 ft over the intervals (ft bgs): 15 to 22.5, 55 to 75, 95 to 120, 130 to 170, 180 to 195, and 210 to 227.5.	44 samples (up to 11 for analysis).	PNNL/Up to 11 samples will be analyzed for several physical parameters (Table A1-12) including particle-size distribution, lithology, and bulk density.
Borehole "D"	Grab quart jar	Grab samples collected every 2.5 ft over the interval (ft bgs): 15 to 227.5. Samples collected at every 10-ft interval will be analyzed.	85 samples (22+ for analysis). Additional analysis may be completed based on initial results and additional intervals may be analyzed as needed.	PNNL/Model development parameters (Table A1-12) will be analyzed as well as some hydraulic and transport parameters including moisture, cation-exchange capacity, uranium isotopic signature analyses, and distribution coefficient. Unused samples to be retained by PNNL for possible future analyses or disposal.
Saturated Zone Sediment Samples				
Borehole "D"	Split-spoon	Split-spoon samples collected at the following intervals (ft): 227.5 to 232.5 ft bgs. Assumes water table contact at 227.5 ft bgs.	Three samples. (Possibly one for PNNL analysis and one sample and one duplicate for WSCF analysis. The WSCF sample will be from the top of the aquifer.)	PNNL/Possibly one sample will be analyzed for some physical parameters (Table A1-12) including particle size distribution, lithology, and bulk density. WSCF/One saturated zone sediment sample and one duplicate sample will be analyzed for the COPCs listed in Tables A1-8 and A1-9.
Borehole "D"	Grab quart jar	Grab samples collected over intervals (ft): 2.5, 5, and 7.5 (assuming water table contact at 227.5 ft bgs, samples will be collected at approximately 230, 232.5 and 235 ft bgs).	Three samples (two for analysis by PNNL.)	PNNL/Two sediment samples will be analyzed for model development parameters (Table A1-12) as well as some hydraulic and transport parameters including cation-exchange capacity, uranium isotopic signature analyses, distribution coefficient, TOC, and TIC. Unused samples to be retained by PNNL for possible future analyses or disposal.
Groundwater Samples				
Borehole "D"	Pump or KABIS	Two samples will be collected once basalt is reached.	Three samples (one sample and one duplicate for analysis by WSCF, and possibly one for isotopic uranium analysis by PNNL).	PNNL/One uranium isotopic signature, if determined applicable, will be analyzed (Table A1-12). WSCF/One groundwater sample and duplicate will be analyzed for COPCs listed in Tables A1-10 and A1-11.

Table A3-5. Sediment and Groundwater Samples for Borehole "D." (3 Pages)

Sample Location	Sample Collection Method	Sample Collection Interval	Number of Samples Collected (Number of Samples Analyzed)[a]	Sample Destination/ Analyte List
Estimated land surface elevation (ft amsl)				627
Estimated depth to groundwater (ft bgs)				227
Estimated depth to basalt (ft bgs)				235
Estimated maximum depth of investigation (ft bgs)				235
Maximum number of collected samples (not including pint archive samples)				138
Number of samples for laboratory analysis [a]				28+
Approximate number of field quality control samples (one equipment blank, two field blanks) [b]				3

[a]The sample collection process is designed for comprehensive study of the unsaturated and saturated zone. As noted, only a subset of these samples will be analyzed. The determination of which samples will be analyzed will be based on sample recovery, sediment type, radiological and vapor field-screening results, borehole geophysics profiles, and preliminary contaminant concentrations.

[b]No volatile organic analysis or semivolatile organic analysis required due to results from previous laboratory analysis and process chemistry of nearby waste site.

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Table A3-6. Sediment and Groundwater Samples for Borehole "E." (3 Pages)

Sample Location	Sample Collection Method	Sample Collection Interval	Number of Samples Collected (Number of Samples Analyzed)*	Sample Destination/ Analyte List
Lithologic Archive Samples				
Borehole "E"	Grab pint jar	Every 5 ft and at major changes in lithology.	48 samples, based on estimated depth (0 for analysis).	Sample archive storage building/no analysis required.
Unsaturated Zone Sediment Samples				
Borehole "E"	Split-spoon	Split-spoon samples collected continuously every 2.5 ft over intervals (ft bgs): 20 to 22.5, 70 to 85, 100 to 120, 135 to 150, 155 to 170, 185 to 195, and 210 to 232.5. Eleven sample intervals are planned for analysis based on soil recovery, soil type, and preliminary contaminant concentrations.	46 samples (up to 11 for analysis).	PNNL/Up to 11 samples will be analyzed for several physical parameters (Table A1-12) including particle-size distribution, lithology, and bulk density. Unused samples to be retained by PNNL for possible future analyses or disposal.
Borehole "E"	Split-spoon	Collected from three split-spoon samples from the intervals (ft bgs): 80 to 82.5, 165 to 167.5, and 190 to 192.5.	Four samples (three samples and one duplicate for analysis).	WSCF/Three vadose-zone sediment and one duplicate will be analyzed for COPCs listed in Tables A1-6 and A1-7.
Borehole "E"	Grab quart jar	Grab samples collected every 2.5 ft over the interval (ft bgs): 20 to 232.5. Samples collected at every 10-ft interval will be analyzed. Additional analysis may be completed based on initial results and additional intervals may be analyzed as needed.	92 samples (22+ for analysis).	PNNL/Model development parameters (Table A1-12) will be analyzed as well as some hydraulic and transport parameters including moisture, cation-exchange capacity, and uranium isotopic signature analyses. Unused samples to be retained by PNNL for possible future analyses or disposal.
Saturated Zone Sediment Samples				
Borehole "E"	Split-spoon	Split-spoon samples collected over intervals (ft bgs): groundwater surface to 2.5, and 7.5 to 10 (assuming water table contact at 234 ft bgs, samples will be collected at approximately 234 to 237.5 and 242.5 to 245 ft bgs).	Two samples. Possibly one for PNNL analysis and one for WSCF analysis. The WSCF sample will be from the top of the aquifer.	PNNL/Possibly one sample will be analyzed for some physical parameters (Table A1-12) including particle size distribution, lithology, and bulk density WSCF/One saturated zone sediment sample will be analyzed for COPCs listed in Tables A1-8 and A1-9.

Table A3-6. Sediment and Groundwater Samples for Borehole "E." (3 Pages)

Sample Location	Sample Collection Method	Sample Collection Interval	Number of Samples Collected (Number of Samples Analyzed)*	Sample Destination/ Analyte List
Borehole "E"	Grab quart jar	Grab samples collected every 2.5 ft over intervals (ft): 234 to 245 (assuming water table contact at 234 ft bgs).	Five samples (two for analysis).	PNNL/Two samples will be analyzed for model development parameters (Table A1-12) as well as some hydraulic and transport parameters including cation-exchange capacity, uranium isotopic signature analyses, distribution coefficient, TOC, and TIC. Unused samples to be retained by PNNL for possible future analyses or disposal.
Groundwater Samples				
Borehole "E"	Pump or KABIS	Two sample are planned for collection of groundwater. One at the first split-spoon interval and the other once basalt is reached.	Five samples (two samples and one duplicate for analysis by WSCF, and possibly two for isotopic uranium analysis by PNNL).	PNNL/Possibly two samples will be analyzed for uranium isotopic signature (Table A1-12), one for each sample interval. WSCF/Two groundwater samples and one duplicate will be analyzed for COPCs listed in Tables A1-10 and A1-11.
Estimated land surface elevation (ft amsl)				634
Estimated depth to groundwater (ft bgs)				234
Estimated depth to basalt (ft bgs)				245
Estimated maximum depth of investigation (ft bgs)				245
Maximum number of collected samples (not including pint archive samples)				154
Number of samples for laboratory analysis*				32+
Approximate number of field quality control samples (two equipment blanks, six field blanks)				8

*The sample collection process is designed for comprehensive study of the unsaturated and saturated zone. As noted, only a subset of these samples will be analyzed. The determination of which samples will be analyzed will be based on sample recovery, sediment type, radiological and vapor field-screening results, borehole geophysics profiles, and preliminary contaminant concentrations.

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Table A3-7. Sediment and Groundwater Samples for Borehole G. (2 Pages)

Sample Location	Sample Collection Method	Sample Collection Interval	Number of Samples Collected (Number of Samples Analyzed)*	Sample Destination/ Analyte List
Lithologic Archive Samples				
Borehole "G"	Grab pint jar	Every 5 ft and at major changes in lithology.	72 samples, based on estimated depth (0 for analysis).	Sample archive storage building/no analysis required.
Unsaturated Zone Sediment Samples				
Borehole "G"	Grab quart jar	Grab samples collected every 2.5 ft over the intervals from 207.5 ft bgs to 222.5 ft bgs.	Seven samples (two for analysis).	PNNL/Model development parameters (Table A1-12) will be analyzed as well as some hydraulic and transport parameters including moisture, cation-exchange capacity, and uranium isotopic signature analyses. Unused samples to be retained by PNNL for possible future analyses or disposal.
Saturated Zone Sediment Samples (Confined Aquifer)				
Borehole "G"	Split-spoon	Split-spoon samples within Rattlesnake Ridge interbed confined aquifer proposed at the following intervals (ft bgs): 312.5 to 315, 335 to 337.5, 357.5 to 360 (assumes top of interbed at 312.5 ft bgs; adjust intervals accordingly).	Six samples (three for analysis for WSCF; up to three analyses for PNNL).	PNNL/Up to three samples will be analyzed for some physical parameters (Table A1-12) including particle size distribution, lithology, and bulk density. WSCF/Three saturated zone sediment samples will be analyzed for the COPCs in Tables A1-8 and A1-9.
Borehole "G"	Grab quart jar	Grab samples collected every 2.5 ft over interval (ft bgs): 312.5 to 360. The samples from intervals 312.5, 335, and 357.5 are proposed for analysis (assumes top of interbed at 312.5 ft bgs; adjust intervals accordingly).	26 samples (3 for analysis).	PNNL/Three samples will be analyzed for model development parameters (Table A1-12) as well as some hydraulic and transport parameters including cation-exchange capacity, distribution coefficient, TOC, and TIC. Unused samples to be retained by PNNL for possible future analyses or disposal.
Groundwater Samples (Confined Aquifer)				
Borehole "G"	Pump or KABIS	Three samples will be collected at the following intervals (ft bgs): 315, 337.5 and 360 (assumes top of interbed aquifer at 312.5; adjust intervals accordingly).	Four samples (three for analysis plus one duplicate).	WSCF/Three groundwater samples will be analyzed for COPCs listed in Tables A1-10 and A1-11. One duplicate water sample also will be collected and analyzed.

Table A3-7. Sediment and Groundwater Samples for Borehole G. (2 Pages)

Sample Location	Sample Collection Method	Sample Collection Interval	Number of Samples Collected (Number of Samples Analyzed)*	Sample Destination/ Analyte List
Estimated surface elevation (ft amsl)				617
Estimated depth to basalt (ft bgs)				222.5
Estimated top of Rattlesnake Ridge interbed (ft bgs)				312.5
Estimated maximum depth of investigation (ft bgs)				360
Maximum number of collected samples (not including pint archive samples)				43
Number of samples for laboratory analysis*				12+
Approximate number of field quality control samples (two equipment blanks, six field blanks)				8

*The sample collection process is designed for comprehensive study of the unsaturated and saturated zone. As noted, only a subset of these samples will be analyzed. The determination of which samples will be analyzed will be based on sample recovery, sediment type, radiological and vapor field-screening results, borehole geophysics profiles, and preliminary contaminant concentrations.

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Table A3-8. Sediment and Groundwater Samples for Borehole "H." (2 Pages)

Sample Location	Sample Collection Method	Sample Collection Interval	Number of Samples Collected (Number of Samples Analyzed)[a]	Sample Destination/ Analyte List
Lithologic Archive Samples				
Borehole "H"	Grab pint jar	Every 5 ft and at major changes in lithology.	51 samples, based on estimated depth (0 for analysis).	Sample archive storage building/no analysis required.
Unsaturated Zone Sediment Samples – None Required[b]				
Saturated Zone Sediment Samples (Confined Aquifer)				
Borehole "H"	Split-spoon	Split-spoon samples collected at intervals (ft bgs): 230 to 232.5, 252.5 to 255, and 282.5 to 285 (assumes top of interbed at 230 ft bgs; adjust intervals accordingly).	Seven samples (three for analysis by WSCF and one duplicate; up to three samples for analysis by PNNL.)	PNNL/Up to three samples will be analyzed for some physical parameters (Table A1-12) including particle size distribution, lithology. and bulk density. WSCF/Three saturated zone sediment samples will be analyzed for COPCs listed in Tables A1-8 and A1-9.
Borehole "H"	Grab quart jar	Grab samples collected every 2.5 ft over interval (ft bgs): 230 to 287.5 (assumes top of interbed at 230 ft bgs; adjust intervals accordingly).	24 samples (3 for analysis, from depths 232.5, 255, and 285 ft).	PNNL/Three samples will be analyzed for model development parameters (Table A1-12) as well as some hydraulic and transport parameters including cation-exchange capacity, TOC, and TIC. Unused samples to be retained by PNNL for possible future analyses or disposal.
Groundwater Samples (Confined Aquifer)				
Borehole "H"	Pump or KABIS	Samples collected at intervals (ft bgs): 232.5, 255, and 285 (assumes top of interbed at 230 ft bgs; adjust intervals accordingly).	Four samples (three for analysis, one duplicate).	WSCF/Three groundwater samples and one duplicate sample will be analyzed for COPCs listed in Tables A1-10 and A1-11.

Table A3-8. Sediment and Groundwater Samples for Borehole "H." (2 Pages)

Sample Location	Sample Collection Method	Sample Collection Interval	Number of Samples Collected (Number of Samples Analyzed)[a]	Sample Destination/ Analyte List
Estimated surface elevation (ft amsl)				573
Estimated depth to basalt (ft bgs)				177
Estimated top of Rattlesnake Ridge interbed (ft bgs)				230
Estimated maximum depth of investigation (ft bgs)				288
Maximum number of collected samples (not including pint archive samples)				34
Number of samples for laboratory analysis[a]				10
Approximate number of field quality control samples (six field blanks, two equipment blanks)				8

[a]The sample collection process is designed for comprehensive study of the unsaturated and saturated zone. As noted, only a subset of these samples will be analyzed. The determination of which samples will be analyzed will be based on sample recovery, sediment type, radiological and vapor field-screening results, borehole geophysics profiles, and preliminary contaminant concentrations.

[b]Unsaturated zone samples will not be collected from well "H" due to the proximity to proposed well "N," where unsaturated samples will be collected and analyzed.

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Table A3-9. Sediment and Groundwater Samples for Borehole "K." (2 Pages)

Sample Location	Sample Collection Method	Sample Collection Interval	Number of Samples Collected (Number of Samples Analyzed)*	Sample Destination/ Analyte List
Lithologic Archive Samples				
Borehole "K"	Grab pint jar	Every 5 ft and at major changes in lithology.	76 samples, based on estimated depth (0 for analysis).	Sample archive storage building/no analysis required.
Unsaturated Zone Sediment Samples				
Borehole "K"	Split-spoon	Split-spoon samples are planned to be collected every 10 ft from 160 ft bgs to 300 ft bgs, and continuously every 2.5 ft over intervals (ft bgs): 195 to 225 and 295 to 302.5. Additional split-spoon samples will be collected at 30-ft intervals between 30 and 160 ft bgs.	33 samples (up to 8 for analysis by PNNL and an estimated 10 samples for analysis by WSCF based on a worst case scenario; one duplicate sample).	PNNL/Up to eight samples will be analyzed for several physical parameters (Table A1-12) including particle-size distribution, lithology, and bulk density. WSCF/An estimated 10 samples from the vadose zone will be analyzed for the COPCs listed in Tables A1-6 and A1-7.
Borehole "K"	Grab quart jar	Grab samples collected every 2.5 ft over the interval (ft bgs): 65 to 302.5. One sample is planned to be analyzed for every 10-ft interval collected. Additional analysis may be completed based on initial results and additional intervals may be analyzed as needed.	96 samples (23+ for analysis).	PNNL/Model development parameters (Table A1-12) will be analyzed as well as some hydraulic and transport parameters including moisture, cation-exchange capacity, and uranium isotopic signature analyses. Unused samples to be retained by PNNL for possible future analyses or disposal.
Saturated Zone Sediment Samples				
Borehole "K"	Split-spoon	Four split-spoon samples are planned to be collected at the following intervals (ft bgs): 305 to 307.5, 315 to 317.5, 341 to 343.5, and 377.5 to 380.	Eight samples (up to three samples for analysis by PNNL and four samples for analysis by WSCF). In addition, one duplicate will be analyzed for WSCF.	PNNL/Up to three samples will be analyzed for some physical parameters (Table A1-12) including particle size distribution, lithology, and bulk density. WSCF/Four saturated zone sediment samples and one duplicate sample will be analyzed for the COPCs listed in Tables A1-8 and A1-9.
Borehole "K"	Grab, quart jar	Grab samples collected over the interval (ft bgs): 305 to 380.	31 samples (up to 8 for analysis).	PNNL/Up to eight samples will be analyzed for model development parameters (Table A1-12) as well as some hydraulic and transport parameters including cation-exchange capacity, distribution coefficient, TOC, and TIC. Unused samples to be retained by PNNL for possible future analyses or disposal.
Groundwater Samples				
Borehole "K"	Pump or KABIS	One sample will be collected at each of the following intervals (ft bgs): 307.5, 317.5, 343.5, and 380	Five samples (four for analysis; one duplicate).	WSCF/Four groundwater samples and one duplicate will be analyzed for COPCs listed in Tables A1-10 and A1-11.

Table A3-9. Sediment and Groundwater Samples for Borehole "K." (2 Pages)

Sample Location	Sample Collection Method	Sample Collection Interval	Number of Samples Collected (Number of Samples Analyzed)*	Sample Destination/ Analyte List
Estimated land surface elevation (ft amsl)				704
Estimated depth to groundwater (ft bgs)				304
Estimated depth to basalt (ft bgs)				380
Estimated maximum depth of investigation (ft bgs)				380
Maximum number of collected samples (not including pint archive samples)				173
Number of samples for laboratory analysis*				43+
Approximate number of field quality control samples (one equipment blank, 18 field blanks)				19

*The sample collection process is designed for comprehensive study of the unsaturated and saturated zone. As noted, only a subset of these samples will be analyzed. The determination of which samples will be analyzed will be based on sample recovery, sediment type, radiological and vapor field-screening results, borehole geophysics profiles, and preliminary contaminant concentrations.

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TOC = total organic carbon.
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Table A3-10. Sediment and Groundwater Samples for Borehole "L." (2 Pages)

Sample Location	Sample Collection Method	Sample Collection Interval	Number of Samples Collected (Number of Samples Analyzed)*	Sample Destination/ Analyte List
Lithologic Archive Samples				
Borehole "L"	Grab pint jar	Every 5 ft and at major changes in lithology.	76 samples, based on estimated depth (0 for analysis).	Sample archive storage building/no analysis required.
Unsaturated Zone Sediment Samples				
Borehole "L"	Split-spoon	Split-spoon samples collected every 10 ft with continuous sampling over intervals (ft bgs): 240 to 260, 280 to 300. Additional split-spoon samples may be collected based on detection of contaminants.	41 samples (up to 6 samples for analysis by PNNL, an estimated 10 samples for analysis by WSCF, and one duplicate analysis).	PNNL/Up to six samples will be analyzed for several physical parameters (Table A1-12) including particle-size distribution, lithology, and bulk density. WSCF/An estimated 10 samples and one duplicate from the vadose zone will be analyzed for the COPCs listed in Tables A1-6 and A1-7.
Borehole "L"	Grab quart jar	Grab samples collected every 2.5 ft over intervals (ft bgs): Ground surface to 305. Sample collected at every 10 ft will be analyzed. Additional analysis may be completed based on initial results and additional intervals may be analyzed as needed.	122 samples (31 for analysis).	PNNL/Model development parameters (Table A1-12) will be analyzed as well as some hydraulic and transport parameters including moisture, cation-exchange capacity, and uranium isotopic signature analyses. Unused samples to be retained by PNNL for possible future analyses or disposal.
Saturated Zone Sediment Samples				
Borehole "L"	Split-spoon	Four split-spoon samples are planned to be collected at the following intervals (ft bgs): 305 to 307.5, 325 to 327.5, 355 to 357.5, and 375 to 377.5 (assumes top of water table at 305 ft bgs; adjust intervals accordingly).	Eight samples (up to three samples for analysis by PNNL; four samples and one duplicate for analysis by WSCF).	PNNL/Up to three samples will be analyzed for some physical parameters (Table A1-12) including particle size distribution, lithology, and bulk density. WSCF/Four saturated zone sediment samples and one duplicate sample will be analyzed for the COPCs listed in Tables A1-8 and A1-9.
Borehole "L"	Grab quart jar	Grab samples collected every 2.5 ft over interval (ft bgs): 305 to 380.	31 samples (8 for analysis).	PNNL/Up to eight samples will be analyzed for model development parameters (Table A1-12) as well as some hydraulic and transport parameters including cation-exchange capacity, distribution coefficient, TOC, and TIC. Unused samples to be retained by PNNL for possible future analyses or disposal.

Table A3-10. Sediment and Groundwater Samples for Borehole "L." (2 Pages)

Sample Location	Sample Collection Method	Sample Collection Interval	Number of Samples Collected (Number of Samples Analyzed)*	Sample Destination/ Analyte List
Groundwater Samples				
Borehole "L"	Pump or KABIS	Water samples collected at split-spoon intervals (ft bgs): 307.5, 327.5, 357.5, and 380 (assumes depth of water table is 305 ft bgs and the top of basalt at 380 ft bgs; adjust intervals accordingly).	Five samples (four samples for analysis by WSCF and one duplicate analysis).	WSCF/Four groundwater samples and one duplicate sample to be analyzed for COPCs listed in Tables A1-10 and A1-11.
Estimated surface elevation (ft amsl)				705
Estimated depth to groundwater (ft bgs)				305
Estimated depth to basalt (ft bgs)				380
Estimated maximum depth of investigation (ft bgs)				380
Maximum number of collected samples (not including pint archive samples)				207
Number of samples for laboratory analysis*				41+
Approximate number of field quality control samples (two equipment blanks, 18 field blanks)				20

*The sample collection process is designed for comprehensive study of the unsaturated and saturated zone. As noted, only a subset of these samples will be analyzed. The determination of which samples will be analyzed will be based on sample recovery, sediment type, radiological and vapor field-screening results, borehole geophysics profiles, and preliminary contaminant concentrations.

KABIS sampler is a product of Sibak Industries, San Marcos, California.

amsl = above mean sea level.
bgs = below ground surface.
COPC = contaminant of potential concern.
PNNL = Pacific Northwest National Laboratory.
TIC = tentatively identified compound.
TOC = total organic carbon.
WSCF = Waste Sampling and Characterization Facility.

Table A3-11. Sediment and Groundwater Samples for Borehole "M." (2 Pages)

Sample Location	Sample Collection Method	Sample Collection Interval	Number of Samples Collected (Number of Samples Analyzed)*	Sample Destination/Analyte List
Lithologic Archive Samples				
Borehole "M"	Grab pint jar	Every 5 ft and at major changes in lithology.	78 samples, based on estimated depth (0 for analysis).	Sample archive storage building/no analysis required.
Unsaturated Zone Sediment Samples				
Borehole "M"	Split-spoon	Split-spoon samples collected every 2.5 ft over intervals (ft bgs): 77.5 to 125, 142 to 162, 180 to 190, 242.5 to 247.5, and 280 to 305. Additional split-spoon samples may be collected based on detection of contaminants.	48 samples (up to 6 for analysis by PNNL).	PNNL/Up to six samples will be analyzed for several physical parameters (Table A1-12) including particle-size distribution, lithology, and bulk density.
Borehole "M"	Grab quart jar	Grab samples collected every 2.5 ft over interval (ft bgs): 80 to 305. Samples collected at every 10-ft interval will be analyzed. Additional analysis may be completed based on initial results and additional intervals may be analyzed as needed.	91 samples (23 for analysis by PNNL).	PNNL/Model development parameters (Table A1-12) will be analyzed as well as some hydraulic and transport parameters including moisture, cation-exchange capacity, and uranium isotopic signature analyses. Unused samples to be retained by PNNL for possible future analyses or disposal.
Saturated Zone Sediment Samples				
Borehole "M"	Split-spoon	Four split-spoon samples will be collected over the following intervals (ft bgs): 310 to 312.5, 325 to 327.5, 351 to 353.5, and 377.5 to 380. (estimated water table contact at 305 ft bgs).	Eight samples (up to three samples for analysis by PNNL; four samples and one duplicate for analysis by WSCF).	PNNL/Up to three samples will be analyzed for some physical parameters (Table A1-12) including particle size distribution, lithology, and bulk density. WSCF/Four saturated zone sediment samples and one duplicate sample will be analyzed for the COPCs in Tables A1-8 and A1-9.
Borehole "M"	Grab quart jar	Grab samples collected every 2.5 ft over intervals (ft bgs): 305 to 380. Samples from intervals 310, 325, 351, and 387.5 will be analyzed.	31 samples (up to 4 for analysis by PNNL).	PNNL/Up to four samples will be analyzed for model development parameters (Table A1-12) as well as some hydraulic and transport parameters including cation-exchange capacity, distribution coefficient, TOC, and TIC. Unused samples to be retained by PNNL for possible future analyses or disposal.
Groundwater Samples				
Borehole "M"	Pump or KABIS	Water samples collected at split-spoon intervals (ft bgs): 312.5, 327.5, 353.5, and 380 (assumes depth of water table is 305 ft bgs and the top of basalt at 380 ft bgs; adjust intervals accordingly).	Seven samples (four samples and one duplicate for analysis by WSCF, and possibly two for isotopic uranium analysis by PNNL).	WSCF/Four groundwater samples and one duplicate sample to be analyzed for COPCs listed in Tables A1-10 and A1-11. PNNL/Possibly two uranium isotopic analysis will be determined based on the results of total uranium from grab and WSCF samples (Table A1-12).

Table A3-11. Sediment and Groundwater Samples for Borehole "M." (2 Pages)

Sample Location	Sample Collection Method	Sample Collection Interval	Number of Samples Collected (Number of Samples Analyzed)*	Sample Destination/Analyte List
Estimated surface elevation (ft amsl)				705
Estimated depth to basalt (ft bgs)				380
Estimated depth to groundwater (ft bgs)				305
Estimated maximum depth of investigation (ft bgs)				380
Maximum number of collected samples (not including pint archive samples)				185
Number of samples for laboratory analysis*				32+
Approximate number of field quality control samples (two equipment blanks, eight field blanks)				10

*The sample collection process is designed for comprehensive study of the unsaturated and saturated zone. As noted, only a subset of these samples will be analyzed. The determination of which samples will be analyzed will be based on sample recovery, sediment type, radiological and vapor field-screening results, borehole geophysics profiles, and preliminary contaminant concentrations.

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TIC = tentatively identified compound.
TOC = total organic carbon.
WSCF = Waste Sampling and Characterization Facility.

Table A3-12. Sediment and Groundwater Samples for Borehole "N." (2 Pages)

Sample Location	Sample Collection Method	Sample Collection Interval	Number of Samples Collected (Number of Samples Analyzed)*	Analyte List
Lithologic Archive Samples				
Borehole "N"	Grab pint jar	Every 5 ft and at major changes in lithology.	37 samples, based on estimated depth (0 for analysis).	Samples for archive storage; no analysis required beyond geologist's sample description.
Unsaturated Zone Sediment Samples				
Borehole "N"	Grab quart jar	Grab samples collected every 2.5 ft over interval (ft bgs): 145 to 172.5. Samples from 165 to 172.5 ft bgs will be analyzed.	12 samples (4 for analysis).	PNNL/Up to four samples will be analyzed for several physical parameters (Table A1-12) including particle-size distribution, lithology, and bulk density.
Saturated Zone Sediment Samples				
Borehole "N"	Split-spoon	Split-spoon samples collected over intervals (ft bgs): 173 to 175.5, 182 to 184.5, and 190.5 to 193 (estimated water table contact at 173 ft bgs).	Three samples (up to two for analysis by PNNL).	PNNL/Up to two samples will be analyzed for some physical parameters (Table A1-12) including particle size distribution, lithology, and bulk density.
Borehole "N"	Split-spoon	Split-spoon samples collected over intervals (ft bgs): 173 to 175.5 and 182 to 184.5.	Two samples (two for analysis).	WSCF/Two saturated zone sediment samples will be analyzed for the COPCs listed in Tables A1-8 and A1-9.
Borehole "N"	Grab quart jar	Grab samples collected at the following depths (ft bgs): 175, 180, 185, and 190.	Four samples (up to four for analysis).	PNNL/Up to four samples will be analyzed for model development parameters (Table A1-12) as well as some hydraulic and transport parameters including cation-exchange capacity, distribution coefficient, TOC, and TIC. Unused samples to be retained by PNNL for possible future analyses or disposal.
Groundwater Samples				
Borehole "N"	Pump or KABIS	Samples collected at split-spoon intervals (ft bgs): 175.5, 184.5, and 193 (estimated water table contact at 173 ft bgs).	Four samples (three for analysis plus one duplicate).	WSCF/Three groundwater samples and one duplicate sample are planned to be analyzed for COPCs listed in Tables A1-10 and A1-11.

Table A3-12. Sediment and Groundwater Samples for Borehole "N." (2 Pages)

Sample Location	Sample Collection Method	Sample Collection Interval	Number of Samples Collected (Number of Samples Analyzed)*	Analyte List
Estimated surface elevation (ft amsl)				573
Estimated depth to basalt (ft bgs)				193
Estimated depth to groundwater (ft bgs)				173
Estimated maximum depth of investigation (ft bgs)				193
Maximum number of collected samples (not including pint archive samples)				25
Number of samples for laboratory analysis*				6+
Approximate number of field quality control samples (two equipment blanks, five field blanks)				7

*The sample collection process is designed for comprehensive study of the unsaturated and saturated zone. As noted, only a subset of these samples will be analyzed. The determination of which samples will be analyzed will be based on sample recovery, sediment type, radiological and vapor field-screening results, borehole geophysics profiles, and preliminary contaminant concentrations.

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TIC = tentatively identified compound.
TOC = total organic carbon.
WSCF = Waste Sampling and Characterization Facility.

Table A3-13. Sediment and Groundwater Samples for Borehole "O." (2 Pages)

Sample Location	Sample Collection Method	Sample Collection Interval	Number of Samples Collected (Number of Samples Analyzed)*	Sample Destination/ Analyte List
Lithologic Archive Samples				
Borehole "O"	Grab pint jar	Every 5 ft and at major changes in lithology.	60 samples, based on estimated depth (0 for analysis).	Sample archive storage building/no analysis required.
Unsaturated Zone Sediment Samples				
Borehole "O"	Grab quart jar	Grab samples collected every 2.5 ft over interval (ft bgs): 250 to 280. Samples from 272.5 to 280 ft bgs will be analyzed.	13 samples (up to 4 samples for analysis).	PNNL/Up to four samples will be analyzed for several physical parameters (Table A1-12) including particle-size distribution, lithology, and bulk density.
Saturated Zone Sediment Samples				
Borehole "O"	Split-spoon	Four split-spoons collected over intervals (ft bgs): 284.5 to 287, 302 to 304.5, 322 to 324.5, and 335 to 337.5 (estimated water table contact at 281 ft bgs).	Seven samples (two samples for analysis by PNNL; four samples and one duplicate for analysis by WSCF).	PNNL/Up to two samples will be analyzed for some physical parameters (Table A1-12) including particle size distribution, lithology, and bulk density. WSCF/Four saturated zone sediment samples will be analyzed for the COPCs listed in Tables A1-8 and A1-9.
Borehole "O"	Grab quart jar	Grab samples collected every 2.5 ft over interval (ft bgs): 282.5 to 340.	22 samples (up to 4 samples for analysis by PNNL)	PNNL/Up to four samples will be analyzed for model development parameters (Table A1-12) as well as some hydraulic and transport parameters including cation-exchange capacity, distribution coefficient, TOC, and TIC. Unused samples to be retained by PNNL for possible future analyses or disposal.
Saturated Zone Water Samples				
Borehole "O"	Pump or KABIS	Samples collected at split-spoon intervals (ft bgs): 287, 304.5, 324.5, and 337.5 (estimated water table contact at 281 ft bgs).	Five samples (four samples for analysis by WSCF, and one duplicate).	WSCF/Four groundwater samples and one duplicate sample are planned to be analyzed for COPCs listed in Tables A1-10 and A1-11.

Table A3-13. Sediment and Groundwater Samples for Borehole "O." (2 Pages)

Sample Location	Sample Collection Method	Sample Collection Interval	Number of Samples Collected (Number of Samples Analyzed)*	Sample Destination/ Analyte List
Estimated surface elevation (ft amsl)				681
Estimated depth to basalt (ft bgs)				336
Estimated depth to groundwater (ft bgs)				281
Estimated maximum depth of investigation (ft bgs)				336
Maximum number of collected samples (not including pint archive samples)				47
Number of samples for laboratory analysis*				10+
Approximate number of field quality control samples (two equipment blanks, eight field blanks)				10

*The sample collection process is designed for comprehensive study of the unsaturated and saturated zone. As noted, only a subset of these samples will be analyzed. The determination of which samples will be analyzed will be based on sample recovery, sediment type, radiological and vapor field-screening results, borehole geophysics profiles, and preliminary contaminant concentrations.

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TIC = tentatively identified compound.
TOC = total organic carbon.
WSCF = Waste Sampling and Characterization Facility.

A3.3.1 Well "A" Sampling Design

Well "A" will provide additional information regarding the lateral extent of uranium contamination in the vadose zone and may assist with identifying the source of uranium contamination. Other possible benefits from this well include resolving possible differing uranium isotopic ratios in the deep vadose zone, providing geology of the deep vadose zone, providing moisture content in various soil horizons, determining the concentration of other radionuclide and chemical contaminants, and providing additional numerical results to refine statistical measurements for modeling risk of contaminant migration and groundwater impact in the future. Below is a detailed description of the sampling and analysis design for each type of collected sample. The sampling design for this well also is presented in Table A3-2 and Figure A3-3.

- <u>Vadose-zone sediment samples</u>:
  - *Split-spoon samples*: Continuous split-spoon samples will be collected from the unsaturated zone over the intervals 65 to 85, 100 to 145, 155 to 175, and 205 to 252.5 ft bgs. The intervals were chosen to align with low-permeability zones using stratigraphic information from nearby well 299-E33-41. From the 53 split-spoon samples collected, up to 8 samples will be processed for physical parameters analyses as described in Table A3-2. Three samples (specifically from split-spoon intervals 224.5 to 227, 235.5 to 238, and 247.5 to 250 ft bgs) will be processed for vadose-zone COPC analyses listed in Table A1-6 and A1-7, along with one duplicate sample.
  - *Grab samples*: Grab samples of the drill cuttings will be collected in quart-size mason jars at 2.5-ft intervals between 60 and 252.5 ft bgs. These samples are in addition to the lithologic archive samples collected every 5 ft over the entire borehole.

    A minimum of 20 of the 78 grab samples from the 60 to 252.5 ft bgs interval will be analyzed for model development, hydraulic, and transport parameters as described in Table A3-2. Included in the hydraulic and transport parameters are isotopic uranium analyses (e.g., up to six samples). The samples will be selected for isotopic uranium analysis based on results of spectral-gamma logging and total uranium analysis.
- <u>Saturated zone sediment samples</u>:
  - *Split-spoon samples*: A total of two split-spoon samples will be collected from the unconfined aquifer sediments from intervals 252.5 to 255, and 257 to 259.5 ft bgs. The thickness of the saturated zone is estimated to be 8 ft. One sample will be processed for analysis of the saturated sediment COPCs listed in Tables A1-8 and A1-9 and one sample will be processed for physical parameters as described in Table A3-2.
  - *Grab samples*: Grab samples of the drill cuttings will be collected in quart-size mason jars at 2.5-ft intervals between 252.5 to 260 ft bgs (or total depth of borehole). Two of the grab samples will be processed for model development, hydraulic, and transport parameters as described in Table A3-2.

- Groundwater samples:

  One depth-discrete groundwater sample will be collected after basalt is reached. The groundwater sample will be analyzed for the COPCs listed in Tables A1-10 and A1-11. In addition, one groundwater sample will be collected for isotopic uranium analysis at the first split-spoon interval in the aquifer.

- Geophysical logging:

  Geophysical logging will be conducted over the entire borehole using methods described in Section A3.4.6.1.

- Hydrologic testing:

  A short-term well-development pumping test is the only planned hydrologic test for well "A." The secondary objective of well development is to collect water-level response data at the pumping well using a pressure transducer and data-logger. The data, when collected during periods of constant-rate pumping, can be considered short-term aquifer-pumping tests. Hydrologic test methods are further described in Section A3.4.1.

A3.3.2 Well "B" Sampling Design

Well "B" will provide information regarding lateral migration of contaminants from the following possible sources: 216-B-7A Crib, B Tank Farm unplanned releases, and the tank 241-BX-102 unplanned release or other potential BX Tank Farm releases. It is unknown if uranium contamination from tank 241-BX-102 extends to this proposed well location or if the uranium reported in geophysical surveys near the groundwater is from another source. This well also will provide an additional control point for the basalt surface in the area. Depth-discrete groundwater samples will be collected to define the extent and concentration of contamination in this apparent deep aquifer anomaly. This well could be used as an extraction well if pump-and-treat activity is determined to be the most feasible alternative for remediation of the growing uranium plume and if aquifer conditions support the use of an extraction well in this location. Below is a detailed description of the sampling and analysis design for each type of collected sample. The sampling design for this well also is presented in Table A3-3 and Figure A3-4.

- Vadose-zone sediment samples:

  - *Split-spoon samples*: Continuous split-spoon samples will be collected from the unsaturated zone over the intervals 40 to 47.5, 60 to 85, and 187.5 to 252.5 ft bgs. Spectral-gamma logs from nearby well 299-E33-18 indicate that gamma-emitting radiological contamination may be present in the lowest interval of the split-spoon samples. Two samples from the lowest interval (225 to 252.5 ft bgs) will be processed for physical property analyses as described in Table A3-3.

    Three samples and a duplicate will be collected from split-spoon intervals 72.5 to 75, 200 to 202.5, and 235 to 237.5 ft bgs. These samples will be processed for analysis of the vadose-zone COPCs listed in Tables A1-6 and A1-7.

- *Grab samples:* Grab samples of the drill cuttings will be collected in quart-size mason jars at 2.5-ft intervals between 42 and 252.5 ft bgs. These samples are in addition to the lithologic archive samples collected every 5 ft over the entire borehole.
- At least 26 of the grab samples (approximately every 10 ft between 42 and 232 ft, and each 2.5-ft sample between 235 and 252.5 ft) will be processed for analyses of physical and model development parameters as described in Table A3-3. Up to three of the grab samples will be processed for isotopic uranium analysis based on results of spectral-gamma logging and total uranium analysis.

- Saturated zone sediment samples:
  - *Split-spoon samples*: The estimated depth to groundwater at proposed well "B" is 253 ft bgs. The thickness of the aquifer is estimated at 12 to 25 ft. Based on this estimate, two split-spoon samples will be collected from the intervals 255 to 257.5 and 263.5 to 266.0 ft bgs. From these split-spoons, two samples will be processed for physical parameters analyses as described in Table A3-3, and two samples will be processed for analyses of the saturated zone sediment COPCs listed in Tables A1-8 and A1-9.
  - *Grab samples:* Grab samples from the saturated sediments will be collected in quart-size mason jars at 2.5-ft intervals between 255 ft and the bottom of the borehole. Three of the projected 11 samples grab samples collected from the unconfined aquifer sediments (at 255, 265, and 273 ft bgs) will be analyzed for model development, hydraulic, and transport parameters as described in Table A3-3.

- Groundwater samples:

  Two depth-discrete groundwater samples will be collected at intervals from 266 ft bgs and at the basalt surface interface and analyzed for the COPCs listed in Tables A1-10 and A1-11. In addition, two groundwater samples will be processed for isotopic uranium analysis at the intervals 257.5 ft bgs and at the basalt surface interface as described in Table A3-3.

- Geophysical logging:

  Geophysical logging will be conducted over the entire borehole using methods described in Section A3.4.6.1.

- Hydrologic testing:

  A slug test, an aquifer-pumping test, and a short-term well-development test are the planned hydrologic tests for borehole "B." Hydrologic test methods are described in Section A3.4.1.

A3.3.3 Well "C" Sampling Design

Well "C" will provide initial vertical profile of the nature and extent of contamination from possibly the following unplanned releases: the assumed cascade line leak between tanks 241-BX-103 and 241-BY-101, spills/leaks associated with tanks 241-BX-106 and

241-BX-102, and assumed leaking tank 241-BY-107. This well also will provide an additional control point for the basalt surface in the area. Depth-discrete groundwater samples will be collected to define the extent and concentration of contamination in the unconfined aquifer. Below is a detailed description of the sampling and analysis design for each type of collected sample. The sampling design for this well also is presented in Table A3-4 and Figure A3-5.

- Vadose-zone sediment samples:
  - *Split-spoon samples*: Fifty-seven continuous split-spoon samples will be collected from the vadose zone from intervals 65 to 85, 100 to 145, 155 to 175, and 205 to 252.5 ft bgs. Up to eight of the split-spoons will be processed for testing of physical parameters as described in Table A3-4. The depth for the physical parameter analyses will be determined based on sample recovery, geologic observation, and geophysical logging. Unused samples will be retained for possible future analysis or disposal.

    Three samples and a duplicate will be collected from split-spoon intervals 160 to 162.5, 217.5 to 220, and 230 to 232.5 ft bgs. These samples will be processed for analysis of the vadose-zone COPCs listed in Tables A1-6 and A1-7.
  - *Grab samples*: Grab samples of the drill cuttings will be collected in quart-size mason jars at 2.5-ft intervals between 60 and 252.5 ft bgs. These samples are in addition to the lithologic archive samples collected every 5 ft over the entire borehole.

    At least 20 of the 82 grab samples from the 60 to 252.5 ft bgs interval will be analyzed for the physical and model development parameters as described in Table A3-4. Samples selected for analyses will include every 10-ft interval (i.e., 60 ft, 70 ft, 80 ft). Additional samples for analysis may be selected based on borehole geophysical logging results and initial analytical results. Several isotopic uranium analyses are planned for samples identified with elevated total uranium.
- Saturated zone sediment samples:
  - *Split-spoon samples*: The estimated depth to groundwater at proposed well "C" is 266 ft bgs. The thickness of the aquifer is estimated at 12 ft. Based on this estimate, two split-spoon samples will be collected from the unconfined aquifer sediments at intervals 255 to 257.5 and 262.5 to 265 ft bgs. One sample may be processed for physical parameters analyses as described in Table A3-4, and one sample from each interval will be processed for the COPCs listed in Tables A1-8 and A1-9.
  - *Grab samples*: Grab samples from the saturated sediments will be collected in quart-size mason jars at 2.5-ft intervals between 255 ft and the bottom of the borehole. Two of the projected five grab samples collected from the unconfined aquifer sediments will be analyzed for model development, hydraulic, and transport parameters as described in Table A3-4.

- Groundwater samples:

  Two depth-discrete groundwater samples will be collected at intervals from 257.5 ft bgs and at the basalt surface interface and analyzed for the COPCs listed in Tables A1-10 and A1-11. In addition, one groundwater sample may be processed for isotopic uranium analysis as described in Table A3-4. The additional isotopic uranium analysis will be determined on total uranium analysis from the WSCF results.

- Geophysical logging:

  Geophysical logging will be conducted over the entire borehole using methods described in Section A3.4.6.1.

- Hydrologic testing:

  A short-term well-development pumping test is the only planned hydrologic test for well "C." The secondary objective of well development is to collect water-level response data at the pumping well using a pressure transducer and data-logger. These data, when collected during periods of constant-rate pumping, can be considered short-term aquifer-pumping tests. Hydrologic test methods are further described in Section A3.4.1.

A3.3.4 Well "D" Sampling Design

Well "D" will provide information regarding the western extent of vadose-zone contamination from the 216-B-49 Crib within the BY Cribs and additional information of the dipping, thin-layer, low-permeability zone. This well also can confirm the top of the basalt in this area and help to identify contaminant dissipation to the west. This well could be used as an extraction well if pump-and-treat activity is determined to be the most feasible alternative for remediation of the increasing technetium plume in this area and if the aquifer is thick enough to support pump and treat at this location. Below is a detailed description of the sampling and analysis design for each type of collected sample. The sampling design for this well also is presented in Table A3-5 and Figure A3-6.

- Vadose-zone sediment samples:

  - *Split-spoon samples*: Continuous split-spoon samples will be collected from the vadose zone from intervals 15 to 22.5, 55 to 75, 95 to 120, 130 to 170, 180 to 195, and 210 to 227.5 ft bgs, for a total of 44 split-spoon samples. Up to 11 of the split-spoons will be processed for testing of physical parameters as described in Table A3-5. The depth for the physical parameter analyses will be determined based on sample recovery, geologic observation, and geophysical logging. Unused samples will be retained for possible future analysis or disposal.

  - *Grab samples*: Grab samples of the drill cuttings will be collected in quart-size mason jars at 2.5-ft intervals between 15 to 227.5 ft bgs. These samples are in addition to the lithologic archive samples collected every 5 ft over the entire borehole. A minimum of 22 of the grab samples will be processed for analyses of physical and model development, hydraulic, and transport parameters as described in Table A3-5. The samples for analysis will be chosen from approximately 10-ft increments throughout the sample interval. Additional analysis may be completed based on geophysical data and initial analytical results.

Up to six of the grab samples will be processed for isotopic uranium analysis. One of these grab samples is planned from each of the following intervals: 20 to 30 ft bgs, 60 to 65 ft bgs, 100 to 105 ft bgs, 185 to 190 ft bgs, 215 ft bgs, and 230 ft bgs. Soil descriptions from geologists' logs and initial soil-model-parameter analyses will be evaluated before final selection of samples for the isotopic analyses.

- Saturated zone sediment samples:
  - *Split-spoon samples*: The estimated depth to groundwater at proposed well "D" is 227.5 ft bgs. The thickness of the aquifer is estimated at 8 ft. Based on this estimate, two split-spoon samples will be collected from the unconfined aquifer at the interval 227.5 to 230 and 230 to 232.5 ft bgs. From these two spilt-spoon samples, two samples may be processed: one sample for analysis of the saturated zone sediments (from the top of aquifer) COPCs as listed in Tables A1-8 and A1-9 and one sample may be analyzed for physical properties as described in Table A3-5. The depth for the physical parameter analyses will be determined based on sample recovery, geologic observation, geophysical logging, and prior data for sediments of similar composition.
  - *Grab samples*: Three grab samples will be collected from the unconfined aquifer sediments. Each sample will be processed for analysis of model development, hydraulic, and transport parameters as described in Table A3-5.
- Groundwater samples:

  Two depth-discrete groundwater samples will be collected after basalt is reached. One sample will be analyzed for the COPCs listed in Tables A1-10 and A1-11. The second sample may be analyzed for isotopic uranium. The additional isotopic uranium analysis will be determined on total uranium analysis from the WSCF results.
- Geophysical logging:

  Geophysical logging will be conducted over the entire borehole using methods described in Section A3.4.6.1.
- Hydrologic testing:

  A short-term well-development pumping test is the only planned hydrologic test for well "D." The secondary objective of well development is to collect water-level response data at the pumping well using a pressure transducer and data-logger. These data, when collected during periods of constant-rate pumping, can be considered short-term aquifer-pumping tests. Hydrologic test methods are further described in Section A3.4.1.

A3.3.5 Well "E" Sampling Design

Well "E" will provide data on anticipated high-moisture zones in the vadose zone to help identify the source of high chloride concentrations detected in nearby wells and to evaluate possible vadose-zone contamination associated with the BY-106 and BY Cribs. This well also will confirm the top of the basalt in this area. Depth-discrete groundwater samples will be collected to define the distribution of contamination in the unconfined aquifer. This well may be used as an extraction well if pump-and-treat activity is determined to be the most feasible alternative for remediation of the growing uranium plume and if the aquifer is thick enough to support pump and treat in this location. Below is a detailed description of the sampling and analysis design for each type of collected sample. The sampling design for this well also is presented in Table A3-6 and Figure A3-7.

- Vadose-zone sediment samples:
  - *Split-spoon samples*: Continuous split-spoon samples will be collected from the vadose zone from the intervals 20 to 22.5, 70 to 85, 100 to 120, 135 to 150, 155 to 170, 185 to 195, and 210 to 234 ft bgs, for a total of 36 samples. From the 36 split-spoon samples collected, up to 11 samples will be processed for testing of physical parameters as described in Table A3-6. The depth of the physical parameter analyses will be determined based on geologic observations, field-screening results, and geophysical logging information. Unused samples will be retained for possible future analysis or disposal. Three samples and a duplicate will be collected from split-spoon intervals 80 to 82.5, 165 to 167.5, and 190 to 192.5 ft bgs. These samples will be processed for analysis of the vadose-zone COPCs listed in Tables A1-6 and A1-7.
  - *Grab samples*: Grab samples of the drill cuttings will be collected in quart-size mason jars at 2.5-ft intervals between 20 to 232.5 ft bgs. These samples are in addition to the lithologic archive samples collected every 5 ft over the entire borehole. A minimum of 22 of the grab samples will be analyzed for the model development, hydraulic, and transport parameters as described in Table A3-6. The samples for analysis will be chosen from approximately 10-ft increments throughout the sample interval. Additional analysis may be completed based on geophysical data and initial analytical results.

    Up to six of the grab samples will be processed for isotopic uranium analysis. One of these grab samples is planned from each of the following intervals: 20 to 30 ft bgs, 60 to 65 ft bgs, 100 to 105 ft bgs, 185 to 190 ft bgs, 215 ft bgs, and 230 ft bgs. Soil descriptions from geologists' logs and initial soil-model-parameter analyses will be evaluated before final selection of samples for the isotopic analyses.
- Saturated zone sediment samples:
  - *Split-spoon samples*: The estimated depth to groundwater at proposed well "E" is 234 ft bgs. The thickness of the aquifer is estimated at 10 ft. Based on this estimate, two continuous split-spoon saturated soil samples will be collected at the intervals of 234 to 237.5 ft bgs and 242.5 to 245 ft bgs. From these two spilt-spoon samples, two samples may be processed: one sample for analysis of the saturated zone sediment (from the top of aquifer) COPCs as listed in Tables A1-8 and A1-9 and one sample may be analyzed for physical properties as described in Table A3-6. The depth for the physical parameter analyses will be determined based on sample recovery, geologic observation, geophysical logging, and prior data for sediments of similar composition.

   - *Grab samples*: Five grab samples will be collected at 2.5-ft intervals over the 10-ft saturated interval. Two of the five grab samples will be processed for model development parameters and isotopic uranium as described in Table A3-6.

- Groundwater samples:

  Depth-discrete groundwater samples will be collected from the top and bottom of the aquifer. Four samples will be collected (i.e., two from each interval). From each interval, one sample will be analyzed for COPCs listed in Tables A1-10 and A1-11, and the second sample may be analyzed for isotopic uranium. The additional isotopic uranium analysis will be determined on total uranium analysis from the WSCF results.

- Geophysical logging:

  Geophysical logging will be conducted over the entire borehole using methods described in Section A3.4.6.1.

- Hydrologic testing:

  A short-term well-development pumping test is the only planned hydrologic test for well "E." The secondary objective of well development is to collect water-level response data at the pumping well using a pressure transducer and data-logger. These data, when collected during periods of constant-rate pumping, can be considered short-term aquifer-pumping tests. Hydrologic test methods are further described in Section A3.4.1.

A3.3.6 Well "G" Sampling Design

Information collected during the drilling and completion of well "F" (completed in fiscal year 2007) was integral to the final sampling design of well "G." The assumed groundwater gradient in the Rattlesnake Ridge confined aquifer is to the north in the vicinity of Waste Management Area (WMA) B/BX/BY and the BY Cribs. Because groundwater analytical data collected from the confined aquifer in well "F," located to the south of well 299-E33-12, was reported with no contamination, the plan for well "G" to the north of well 299-E33-12 was not changed. The "F" well data are consistent with the conceptual model that well 299-E33-12 was a conduit for contamination within the Rattlesnake Ridge confined aquifer and not some other upgradient source. Well "G" will be drilled and completed as a downgradient well to well 299-E33-12 to evaluate the down-gradient extent of contamination. Below is a detailed description of the sampling and analysis design for each type of collected sample. The sampling design also is presented in Table A3-7 and Figure A3-8.

- Vadose sediment samples:

  The proposed location of well "G" (Figure A1-1) occurs along the margin of the basalt high; therefore, no groundwater (unconfined aquifer) is expected. As a result, only minimal characterization of the vadose zone at this location is planned.

   - *Split-spoon samples*: No split-spoon samples are planned at this location.

  - *Grab samples*: Grab samples of the drill cuttings will be collected every 2.5 ft in quart-size mason jars over the interval from 207.5 ft bgs to 222.5 ft bgs. This interval corresponds to sediments 15 ft above the Elephant Mountain Member basalt. The grab samples will be processed for analysis of the model development parameters as described in Table A3-7 and possibly for isotopic uranium.

- <u>Saturated zone sediment samples (confined aquifer sediments)</u>:
  - *Split-spoon samples:* The estimated depth to top of the confined aquifer (top of Rattlesnake Ridge interbed) at the proposed well "G" is 312.5 ft bgs. The thickness of the aquifer is estimated at 47.5 ft. Based on this estimate, three split-spoon samples will be collected from the intervals 312.5 to 315, 335 to 337.5, and 357.5 to 360 ft bgs. One and possibly each of the three split-spoons will be processed for analysis of the physical parameters as described in Table A3-7. Soil descriptions from geologists' logs and geophysical logging surveys will be evaluated before final selection of samples for analysis. Each of the three split-spoons will be processed for analysis of COPCs listed in Tables A1-8 and A1-9.
  - *Grab samples:* Grab samples are planned to be collected every 2.5 ft over the entire confined aquifer interval (assumed 312.5 to 360 ft bgs). These grab samples are in addition to the lithologic archive samples collected every 5 ft over the entire borehole. Three samples for model development, hydraulic, and transport parameters will be processed from grab samples collected at estimated depths of 312.5, 335, and 357.5 ft bgs as described in Table A3-7. Adjustments to these depths will made based on depth of contact of the Rattlesnake Ridge interbed. Unused samples will be retained for possible future analyses or disposal.

- <u>Groundwater samples</u>:

  Three depth-discrete groundwater samples are planned to be collected at depths to coincide with the split-spoon intervals of 315, 337.5, and 360 ft bgs. Groundwater samples will be processed for analysis of COPCs listed in Tables A1-10 and A1-11.

- <u>Geophysical logging</u>:

  Geophysical logging will be conducted over the entire borehole using methods described in Section A3.4.6.1.

- <u>Hydrologic testing</u>:

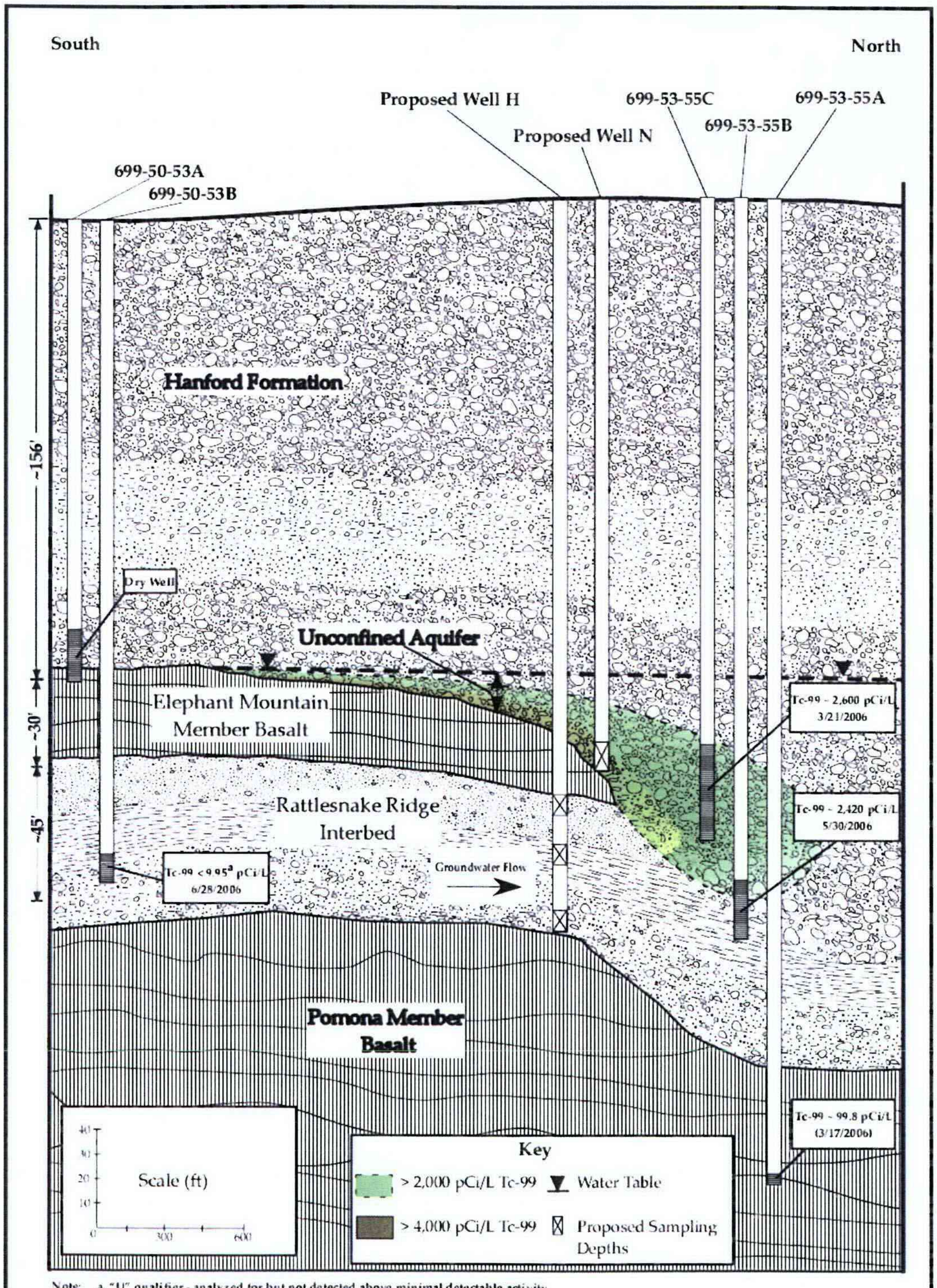
  A short-term well-development pumping test is the only planned hydrologic test for well "G." The secondary objective of well development is to collect water-level response data at the pumping well using a pressure transducer and data-logger. These data, when collected during periods of constant-rate pumping, can be considered short-term aquifer-pumping tests. Hydrologic test methods are further described in Section A3.4.1.

A3.3.7 Well "H" Sampling Design

Wells "H" and "N" will provide groundwater chemical and hydraulic data near the vicinity of the eroded "window" in the Elephant Mountain Member basalt. Specifically, the well will be used to evaluate the confined aquifer (Rattlesnake Ridge interbed). Figure A3-15 depicts the target depths and locations for proposed wells "H" and "N." Well "H" was proposed to determine if Tc-99 and nitrate contamination detected at depth in proximal wells 699-53-55A and 699-53-55B located in the basalt erosional window may extend into the confined aquifer. Well "H" is to be located within 10 ft of well "N." Proposed well "N" is targeted to be completed in unconsolidated sediments above the Elephant Mountain Member basalt unit, near the assumed edge of an eroded window through the Elephant Mountain Member basalt. Well "N" will be drilled and completed before well "H." During the drilling of well "H," drilling may pause when the top of the Elephant Mountain Member basalt is encountered. At that time, an aquifer-pumping test may occur within well "N" and borehole "H." An additional aquifer test may be conducted once the borehole "H" is drilled through the Elephant Mountain Member basalt. This second test, if completed, will attempt to evaluate continuity between the two aquifers in the vicinity of the eroded basalt window. Below is a detailed description of the sampling and analysis design for each type of collected sample. The sampling design also is presented in Table A3-8 and Figure A3-9.

- Vadose-zone sediment samples:
  - *Split-spoon samples*: No split-spoon samples will be collected from the vadose zone due to the proximal distance to well "N."
  - *Grab samples:* Grab samples in the vadose zone for well "H" will not be collected because samples from the vadose zone will be collected at adjacent well "N."
- Saturated zone sediment samples (confined aquifer):
  - *Split-spoon samples*: The estimated depth to top of the confined aquifer (top of Rattlesnake Ridge interbed) at proposed well "H" is 230 ft bgs. The thickness of the aquifer is estimated at 58 ft. Split-spoon samples within the confined aquifer are proposed at the intervals 230 to 232.5, 252.5 to 255, and 282.5 to 285 ft bgs. Up to three split-spoon samples will be analyzed by the Pacific Northwest National Laboratory for physical properties as described in Table A3-8. Each of the saturated sediment intervals collected will be analyzed for the COPCs listed in Tables A1-8 and A1-9. In addition, one duplicate sample will be analyzed from one of the three intervals collected.
  - *Grab samples:* Grab samples will be collected every 2.5 ft over the entire confined aquifer interval (assumed 230 to 287.5 ft bgs). These grab samples are in addition to the lithologic archive samples collected every 5 ft over the entire borehole. Grab samples of the drill cuttings will be collected in quart-size mason jars. The grab samples corresponding to the split-spoon intervals (232.5, 255, and 287.5 ft bgs) will be analyzed for the model development, hydraulic, and transport parameters described in Table A3-8. Adjustments to these depths will be made based on depth of contact of the Rattlesnake Ridge interbed. Unused samples will be retained for possible future analyses or disposal.

Figure A3-15. Schematic Showing Target Sampling
Intervals for Proposed Wells "H" and "N."



Note: a. "U" qualifier - analyzed for but not detected above minimal detectable activity

- Groundwater samples:

  Three depth-discrete groundwater samples will be collected at depths to coincide with the split-spoon sample depths of 232.5, 255, and 285 ft bgs. Groundwater samples will be processed for analysis of the COPCs listed in Tables A1-10 and A1-11.

- Geophysical logging:

  Geophysical logging will be conducted over the entire borehole using methods described in Section A3.4.6.1.

- Hydrologic testing:

  Well "H" may be designated as the observation well during an aquifer-pumping test at nearby well "N." An additional aquifer test (method to be determined) may be conducted after borehole "H" is drilled through the Elephant Member basalt surface. This second test, if completed, will evaluate continuity between the two aquifers in the vicinity of the eroded basalt window. A short-term well-development pumping test also will occur during well development of well "H." Hydrologic test methods are further described in Section A3.4.1.

A3.3.8 Well "K" Sampling Design

Well "K" will evaluate the extent of contamination in the deep vadose zone and groundwater near the 216-B-6 Reverse Well. There is uncertainty whether the depth of the screen interval for the reverse well is 75, 161, or 302 ft bgs. One document (HW-55176, *Index of CPD Crib Building Numbers Designs of CPD Radioactive Liquid Waste Disposal Sites*), indicates that the well is 160 ft bgs, with a screened interval from 75 to 160 ft bgs. Recent SIM estimates indicate that the median inventory for chromium is nearly 2,500 kg and mobile radionuclides did not exceed 1 Ci. The highest mobile radionuclide concentrations (according to the SIM) were associated with tritium and technetium. Nitrate, chloride, and sodium concentrations also were significant. Below is a detailed description of the sampling and analysis design for each type of collected sample. The sampling design also is presented in Table A3-9 and Figure A3-10.

- Vadose-zone sediment samples:

  – *Split-spoon samples*: Split-spoon samples will be collected from the vadose zone at a minimum of 30-ft intervals from 30 to 160 ft bgs, and at 10-ft intervals from 160 ft bgs to groundwater, with continuous split-spoons from 195 to 225 ft bgs and 295 to 302.5 ft bgs. Of the estimated 33 samples collected, up to 8 samples will be processed for analysis of physical parameters as described in Table A3-9. The depths for these eight samples will be determined based on sample recovery, field-screening results, geologic observation, and geophysical logging information. Ten of the split-spoon samples, including intervals every 30 ft from 160 ft to groundwater, will be processed for analysis of the COPCs listed in Tables A1-6 and A1-7. Unused samples will be retained for possible future analysis or disposal.

  – *Grab samples*: Grab samples of the drill cuttings will be collected in quart-size mason jars at 2.5-ft intervals from 65 ft bgs to groundwater (estimated at 304 ft bgs). These samples are in addition to the lithologic archive samples collected every 5 ft over the entire borehole. A minimum of 23 of the grab samples will be analyzed for the model development, hydraulic, and transport parameters described in Table A3-9. The samples for analysis will be chosen from approximately 10-ft increments throughout the sample interval. Three of the samples will be processed for isotopic uranium analysis. Additional samples may be processed for analysis based on geophysical data and initial analytical results. Unused samples will be retained for possible future analysis or disposal.

- Saturated zone sediment samples:
  - *Split-spoon samples*: The estimated depth to top of the unconfined aquifer at proposed well "K" is 304 ft bgs. The thickness of the aquifer is estimated at 76 ft. Based on this estimate, four split-spoon samples will be collected from the unconfined aquifer sediments at intervals 305 to 307.5, 315 to 317.5, 341 to 343.5, and 377.5 to 380 ft bgs. Up to three of the split-spoon samples will be processed for physical parameters as listed in Table A3-9. The samples for analysis will be determined based on sample recovery, field-screening results, geologic observation, and geophysical logging information. Each of the samples collected will be analyzed for the saturated zone sediment COPCs listed in Tables A1-8 and A1-9.
  - *Grab samples:* Grab samples of the drill cuttings will be collected in quart-size mason jars at 2.5-ft intervals over the entire thickness of the unconfined aquifer (estimated 305 to 380 ft bgs). Up to eight of the estimated 31 samples will be processed for analysis of the model development, hydraulic, and transport parameters as described in Table A3-9.
- Groundwater samples:

  Four depth-discrete groundwater samples will be collected corresponding to the split-spoon sample depths 307.5, 317.5, 343.5, and 380 ft bgs. The groundwater samples will be analyzed for the COPCs listed in Tables A1-10 and A1-11.
- Geophysical logging:

  Geophysical logging will be conducted over the entire borehole using methods described in Section A3.4.6.1.
- Hydrologic testing:

  A short-term well-development pumping test is the only planned hydrologic test for well "K." The secondary objective of well development is to collect water-level response data at the pumping well using a pressure transducer and data-logger. These data, when collected during periods of constant-rate pumping, can be considered short-term aquifer-pumping tests. Hydrologic test methods are further described in Section A3.4.1.

A3.3.9 Well "L" Sampling Design

Well "L" will provide information on potential vadose-zone contamination associated with historical discharges of high-salt waste near the 216-C-1 Hot Semiworks Plant. In particular, the well will investigate vadose-zone contamination, vadose-zone sediment properties, and current groundwater contamination in this area. Below is a detailed description of the sampling and analysis design for each type of collected sample. The sampling design also is presented in Table A3-10 and Figure A3-11.

- Vadose-zone sediment samples:
  - *Split-spoon samples*: Split-spoon samples will be collected from the vadose zone at 10-ft intervals from ground surface to groundwater and continuously over the intervals 240 to 260 and 280 to 300 ft bgs. Of the 41 samples collected, up to 6 samples will be processed for physical parameters testing as described in Table A3-10. The determination of which samples will be analyzed will be based on sample recovery, sediment type, radiological and vapor field-screening results, borehole geophysics profiles, and preliminary contaminant concentrations. Ten samples will be processed for analysis of the vadose-zone COPCs as listed in Tables A1-6 and A1-7. Unused samples will be retained for possible future analysis or disposal.
  - *Grab samples*: Grab samples of the vadose-zone drill cuttings will be collected in quart-size mason jars at 2.5-ft intervals from ground surface to 305 ft bgs. These samples are in addition to the lithologic archive samples collected every 5 ft over the entire borehole. A minimum of 31 of the grab samples will be analyzed for the model development, hydraulic, and transport parameters described in Table A3-10. The samples for analysis will be chosen from approximately 10-ft increments throughout the sample interval. Three of the samples will be processed for isotopic uranium analysis. Additional samples may be processed for analysis based on geophysical data and initial analytical results. Unused samples will be retained for possible future analysis or disposal.
- Saturated zone sediment samples:
  - *Split-spoon samples:* The estimated depth to top of the unconfined aquifer at proposed well "L" is 305 ft bgs. The thickness of the aquifer is estimated at 75 ft. A total of four split-spoon samples will be collected from the unconfined aquifer sediments at intervals 305 to 307.5, 325 to 327.5, 355 to 357.5, and 375 to 377.5 ft bgs. Up to three of the split-spoon samples will be processed for physical parameters as listed in Table A3-10. The samples for analysis will be determined based on sample recovery, field-screening results, geologic observation, and geophysical logging information. Each of the samples collected will be analyzed for the saturated zone sediment COPCs listed in Tables A1-8 and A1-9.
  - *Grab samples:* Grab samples of the drill cuttings will be collected in quart-size mason jars at 2.5-ft intervals over the entire thickness of the unconfined aquifer (estimated 305 to 380 ft bgs). Up to 8 of the estimated 31 samples will be processed for analysis of the model development, hydraulic, and transport parameters as described in Table A3-10.
- Groundwater samples:

  Four depth-discrete groundwater samples will be collected corresponding to the split-spoon sample depths 307.5, 327.5, 357.5, and 377.5 ft bgs. The groundwater samples will be analyzed for the COPCs listed in Tables A1-10 and A1-11.

- Geophysical logging:

  Geophysical logging will be conducted over the entire borehole using methods described in Section A3.4.6.1.

- Hydrologic testing:

  A short-term well-development pumping test is the only planned hydrologic test for well "L." The secondary objective of well development is to collect water-level response data at the pumping well using a pressure transducer and data-logger. These data, when collected during periods of constant-rate pumping, can be considered short-term aquifer-pumping tests. Hydrologic test methods are further described in Section A3.4.1.

A3.3.10 Well "M" Sampling Design

Well "M" is proposed as a replacement groundwater monitoring well for well 299-E28-16, which was located near the 216-B-12 Crib. The 216-B-12 Crib received large inventories of uranium, plutonium, and cesium. Waste discharges exceeded the available sediment pore space by as much as 28 times during the operational period of 1952 and 1973 (WMP-28945). The proposed location of well "M" is intended to provide additional data on the nature and extent of vadose-zone contamination associated with the 216-B-12 Crib. This well also will confirm the top of the basalt in this area. Depth-discrete groundwater samples will be collected to define the distribution of contamination (particularly uranium) in the unconfined aquifer. Below is a detailed description of the sampling and analysis design for each type of collected sample. The sampling design also is presented in Table A3-11 and Figure A3-12.

- Vadose-zone sediment samples:
  - *Split-spoon samples*: Split-spoon samples will be collected from the vadose zone continuously over the intervals 77.5 to 125, 142 to 162, 180 to 190, 242.5 to 247.5, and 280 to 305 ft bgs. From the estimated 48 samples collected, up to 6 samples will be processed for testing of physical parameters as listed in Table A1-12. The determination of which samples will be analyzed will be based on sample recovery, sediment type, radiological and vapor field-screening results, borehole geophysics profiles, and preliminary contaminant concentrations. Unused samples will be retained for possible future analysis or disposal.
  - *Grab samples*: Grab samples of the vadose-zone drill cuttings will be collected in quart-size mason jars at 2.5-ft intervals between 80 and 305 ft bgs. These samples are in addition to the lithologic archive samples collected every 5 ft over the entire borehole. A minimum of 23 of the grab samples will be analyzed for the model development, hydraulic, and transport parameters described in Table A3-11. The samples for analysis will be chosen from approximately 10-ft increments throughout the sample interval. Up to four of the samples will be processed for isotopic uranium analysis. Samples will be selected based on geophysical data and initial analytical results. Unused samples will be retained for possible future analysis or disposal.

- Saturated zone sediment samples:
  - *Split-spoon samples*: The estimated depth to top of the unconfined aquifer at proposed well "M" is 305 ft bgs. The thickness of the aquifer is estimated at

75 ft. Four split-spoon samples will be collected from the unconfined aquifer sediments. The samples will be collected at intervals 310 to 312.5, 325 to 327.5, 351 to 353.5, and 377.5 to 380 ft bgs. Up to three of the split-spoon samples will be processed for physical parameters as listed in Table A3-11. The samples for analysis will be determined based on sample recovery, field-screening results, geologic observation, and geophysical logging information. Each of the samples collected will be analyzed for the saturated zone sediment COPCs listed in Tables A1-8 and A1-9.

– *Grab samples*: Grab samples of the drill cuttings will be collected in quart-size mason jars at 2.5-ft intervals over the entire thickness of the unconfined aquifer (estimated from 305 to 380 ft bgs). These samples are in addition to the lithologic archive samples collected every 5 ft over the entire borehole. Up to four of the estimated 31 samples will be processed for analysis of the model development, hydraulic, and transport parameters as described in Table A3-11. Two isotopic uranium analyses also may be performed on selected samples depending on initial results.

- Groundwater samples:

  Four depth-discrete groundwater samples will be collected at intervals corresponding to the split-spoon samples of the unconfined aquifer (312.5, 327.5, 353.5, and 380 ft bgs). The groundwater samples will be analyzed for the COPCs listed in Tables A1-10 and A1-11. Isotopic uranium isotopic signature analysis also may be performed on selected samples depending on total uranium results.

- Geophysical logging:

  Geophysical logging will be conducted over the entire borehole using methods described in Section A3.4.6.1.

- Hydrologic testing:

  A short-term well-development pumping test is the only planned hydrologic test for well "M." The secondary objective of well development is to collect water-level response data at the pumping well using a pressure transducer and data-logger. These data, when collected during periods of constant-rate pumping, can be considered short-term aquifer-pumping tests. Hydrologic test methods are further described in Section A3.4.1.

A3.3.11 Well "N" Sampling Design

Well "N" will provide groundwater chemical and hydraulic data near the vicinity of the eroded "window" in the Elephant Mountain Member basalt. Specifically, the well will be used to better evaluate the nature (i.e., whether it exists in a high-density aqueous phase) and extent of technetium contamination detected in nearby wells 699-53-55A and 699-53-55B. Figure A3-15 depicts the target depths and locations for proposed wells "N" and "H." Proposed well "N" is targeted to be completed in unconsolidated sediments above the Elephant Mountain Member basalt unit, near the edge of an eroded window through the Elephant Mountain Member basalt. Confined aquifer well "H" will be drilled within 10 ft of well "N." Well "N" will be drilled and completed before well "H." During the drilling of well "H," drilling will pause when the top of the Elephant Mountain Member basalt is encountered. At that time, an aquifer-pumping test is planned, with well "N" as the pumping well and borehole "H" as the observation well. Below is a detailed description of the sampling and analysis design for each type of collected sample. The sampling design also is presented in Table A3-12 and Figure A3-13.

- Vadose-zone sediment samples:
  - *Split-spoon samples*: No split-spoon samples will be collected from the vadose zone due to the considerable distance the proposed location is from the nearest waste site. It is assumed that all contamination at this location will occur in the aquifer.
  - *Grab samples*: Grab samples of the drill cuttings will be collected in quart-size mason jars every 2.5 ft over the interval 145 to 172.5 ft bgs. These grab samples are in addition to the lithologic archive samples collected every 5 ft over the entire borehole. The grab samples from 165 to 172.5 ft bgs (a total of four) will be processed for analysis of the model development parameters described in Table A3-12. Unused samples will be retained by the Pacific Northwest National Laboratory for possible future analyses or disposal.
- Saturated zone sediment samples:
  - *Split-spoon samples*: The estimated depth to top of the unconfined aquifer at proposed well "N" is 173 ft bgs. The thickness of the aquifer is estimated at 20 ft. Split-spoon samples within the unconfined aquifer are proposed at the intervals 173 to 175.5, 182 to 184.5, and 190.5 to 193 ft bgs. Up to two of the three split-spoon samples will be processed for analysis of physical parameters as described in Table A3-12. The determination of which samples will be analyzed will be based on sample recovery, soil type, radiological and vapor field-screening results, borehole geophysics profiles, and preliminary contaminant concentrations. In addition, the uppermost and bottom split-spoons will be processed for analysis of the saturated sediment COPCs as listed in Tables A1-8 and A1-9.
  - *Grab samples*: Grab samples of the drill cuttings will be collected in quart-size mason jars at depths of 175, 180, 185, and 190 ft bgs. Up to four grab samples will be processed for analysis of the model development, hydraulic, and transport parameters as described in Table A3-12.
- Groundwater samples:

  Three groundwater samples are planned to be collected corresponding to the split-spoon intervals (175.5, 184.5, and 193 ft bgs). These three groundwater samples plus a duplicate will be analyzed for the COPCs listed in Tables A1-10 and A1-11.
- Geophysical logging:

  Geophysical logging will be conducted over the entire borehole using methods described in Section A3.4.6.1.

- Hydrologic testing:

  A constant-discharge pumping test will be conducted in completed well "N" with borehole "H" as the observation well. This will occur when the borehole "H" encounters the surface of the Elephant Mountain Member basalt. An additional aquifer test will be conducted after borehole "H" is to total depth at the surface of the Pomona Member basalt surface. This second test will evaluate continuity between the two aquifers in the vicinity of the eroded basalt window. A short-term well-development pumping test also will occur during well development of well "N." Hydrologic test methods are further described in Section A3.4.1.

A3.3.12 Well "O" Sampling Design

The location of well "O" is proposed for the vicinity of WMA-C. The precise location of the well will be determined following further evaluation of groundwater flow using borehole deviation surveys and plume geometries in the vicinity. This well will be used to evaluate vertical and horizontal distribution of Tc-99 and nitrate downgradient of WMA-C. Below is a detailed description of the sampling and analysis design for each type of collected sample. The sampling design also is presented in Table A3-13 and Figure A3-14.

- Vadose-zone sediment samples:
  - *Split-spoon samples*: No split-spoon samples will be collected from the vadose zone during drilling at well "O."
  - *Grab samples*: Grab samples of the drill cuttings will be collected in quart-size mason jars every 2.5 ft over the interval 250 to 280 ft bgs. These grab samples are in addition to the lithologic archive samples collected every 5 ft over the entire borehole. The grab samples from 272.5 to 280 ft bgs (total of four) will be processed for analysis of the model development parameters as described in Table A3-13. Unused samples will be retained by the Pacific Northwest National Laboratory for possible future analyses or disposal.
- Saturated zone sediment samples:
  - *Split-spoon samples*: The estimated depth to top of the unconfined aquifer at proposed well "O" is 281 ft bgs. The thickness of the aquifer is estimated at 60 ft. Four split-spoon samples will be collected from the intervals 284.5 to 287, 302 to 304.5, 322 to 324.5 and 335 to 337.5 ft bgs. From these four split-spoons, up to two samples will be processed for physical parameter testing as described in Table A3-13. The determination of which samples will be analyzed for the physical parameters will be based on sample recovery, soil type, radiological and vapor field-screening results, borehole geophysics profiles, and preliminary contaminant concentrations. Four samples (one from each split-spoon) will be processed for analysis of the saturated zone sediment COPCs listed in Tables A1-8 and A1-9.
  - *Grab samples*: Grab samples of the drill cuttings will be collected in quart-size mason jars every 2.5 ft over the interval 282.5 to 340 ft bgs. These grab samples are in addition to the lithologic archive samples collected every 5 ft over the entire

borehole. Up to four of the grab samples will be analyzed for model development, hydraulic, and transport parameters as described in Table A3-13.

- Groundwater samples:

  Four depth-discrete groundwater samples will be collected at intervals corresponding to the split-spoon samples (287, 304.5, 324.5, and 337.5 ft bgs). Groundwater samples from each of the four depths will be analyzed for the COPCs listed in Tables A1-10 and A1-11. One duplicate sample also will be collected and analyzed.

- Geophysical logging:

  Geophysical logging will be conducted over the entire borehole using methods described in Section A3.4.6.1.

- Hydrologic testing:

  A short-term well-development pumping test is the only planned hydrologic test for well "M." The secondary objective of well development is to collect water-level response data at the pumping well using a pressure transducer and data-logger. These data, when collected during periods of constant-rate pumping, can be considered short-term aquifer-pumping tests. Hydrologic test methods are further described in Section A3.4.1.

A3.3.13 Sampling Requirements for All Wells

The following sampling methods will be used at each well.

- Geologic/archive samples:

  Cuttings will be collected every 5 ft or at major changes in lithology for the purposes of geologic description and archived storage. Cuttings will be collected in pint-size glass jars (one per interval). Geologic descriptions using FH procedures will be performed by the well site geologist.

- Split-spoon samples:

  The split-spoon samplers will be equipped with four, 6-in.-long LEXAN[2] or stainless-steel liners to provide segregation of the split-spoon sample after collection. The split-spoon sample liners will be capped, taped, and labeled according to FH procedures. A grab sample will be collected from any interval where an insufficient or no split-spoon sample is obtained.

- Groundwater samples:

  For all groundwater-sampling activities, a pumped groundwater sample is the preferred sampling method. This activity will be conducted using the contractor's submersible pump (5 hp, capable of 5 to 25 gal/min). If inadequate water column is available for a pumped sample to be successfully collected, a KABIS sample may be authorized by FH or FH's technical representative. Unconfined aquifer samples will be collected with the

[2] LEXAN is a registered trademark of General Electric Company, New York, New York.

well casing positioned approximately 1 to 2 ft above the borehole depth. Confined aquifer samples will be collected with an approximately 1-ft open hole below the bottom of the casing at the selected depths.

A3.4 OTHER INVESTIGATIVE METHODS

A3.4.1 Hydrologic Testing

Four types of aquifer tests are identified for this data collection effort: slug tests, constant-discharge single- or multiple-well pumping tests, tests during well development, and single-well tracer tests. The test method employed is dependent upon the observed geologic and hydrologic conditions, as well as the overall water quality at each borehole location (Table A3-14). Each of these proposed aquifer test methods is described below.

Table A3-14. Planned Hydrologic Testing.

Type of Test	Purpose	Target Interval	Well Locations
Slug test	Provide initial estimates of hydraulic properties	Unconfined aquifer	"B" and "N"
Aquifer-pumping test	Identify aquifer parameters for evaluation of remedial alternatives	Unconfined aquifer	"B" and " N"
Short-term well-development pumping test	Generate an estimate of aquifer transmissivity and evaluate well specific capacity	Unconfined aquifer	"A," "B," "C," "D," "E," "I," "J," "K," "L," "M," "N," and "O"
		Confined aquifer	"F," "G," and "H"
Single-well tracer test	Yield a profile of hydraulic conductivity, estimate flow velocity independent of gradient measurement and stress tests	Unconfined aquifer	Selected existing wells near C Tank Farm, selected existing wells northwest of BY Tank Farm, and well 699-53-55

A3.4.2 Slug Tests

Slug tests are commonly used at the Hanford Site to provide initial estimates of hydraulic properties (e.g., range and spatial/vertical distribution of hydraulic conductivity) because of their ease of implementation and relatively short duration. Additionally, slug tests do not require management of discharge water, as is required by pumping test methods. Because of the small displacement volumes employed during slug tests, the subsequent hydraulic property data are representative of conditions relatively close to the well.

Multi-stress slug tests will be performed in selected boreholes before well completion. These tests involve injecting (i.e., injection test) and removing (i.e., withdrawal test) a slugging rod of known displacement volume. If time allows, two different-size slugging rods will be used to impart varying stress levels for individual slug tests. The slug tests are repeated at each stress level to assess reproducibility of the test results. Comparison of the normalized slug-test responses is useful for assessing the effectiveness of well development and the presence of near-well heterogeneities and dynamic skin effects, as noted in Butler, 1997, *The Design, Performance, and Analysis of Slug Test.*

The slug-test data will be analyzed using the semi-empirical, straight-line analysis method described in Bouwer and Rice, 1976, "A Slug Test for Determining Hydraulic Conductivity of Unconfined Aquifers with Completely or Partially Penetrating Wells"; Bouwer, 1989, "The Bower and Rice Slug Test – An Update"; and the type-curve-matching method for unconfined aquifers presented in Butler, 1997.

A3.4.3 Short-Term Well-Development Pumping Tests

To model groundwater flow through an aquifer, aquifer parameters (including hydraulic conductivity, aquifer thickness, and storage coefficient) are necessary. Analysis of data from single-well aquifer tests will generate an estimate of aquifer transmissivity. Because transmissivity is the product of hydraulic conductivity and aquifer thickness, such pumping tests can yield average values of hydraulic conductivity, if aquifer thickness is known.

All new wells at the Hanford Site are developed before being accepted for production (i.e., extraction or injection) or monitoring activities. For production wells, development enhances well performance. For monitoring wells, the primary objective of development is to increase the hydraulic connection with the aquifer, thus enabling collection of representative samples and improving well efficiency (maximum production at a minimum drawdown). Well development generally is concluded once the turbidity of the pumped water is measured at or below 5 nephelometric turbidity units. The secondary objective of well development is to collect water-level response data at the pumping well using a pressure transducer and data-logger. These tests, when they are conducted by pumping at a constant discharge rate, can be considered short-term aquifer-pumping tests. This is the most useful with wells screened across the confined aquifers. Unconfined aquifers have a more complex "gravity drainage response" to pumping, which generally means that for an accurate estimate of transmissivity, the well must be pumped for a longer duration than for a confined aquifer.

The short-term well-development aquifer-pumping tests generally are conducted for 100 minutes or less, followed by at least a 30-minute recovery test. Water-level response is recorded using a data-logger and pressure transducer. The geologist records the discharge rate periodically, either from a totalizing meter on the discharge pipe or using a bucket and stopwatch (typically both). Duration of the pumping test is always limited by the capacity of the purgewater truck, which receives the pumped water. Water is never pumped to the ground surface due to possible spread of contamination.

Data obtained during the short-term well-development aquifer-pumping tests typically are analyzed for transmissivity using straight-line methods on a semi-log graph. Log-log methods of analysis are available when conducting multiple well tests, using a pumping well and one or more observation wells. Multiple-well tests are preferred, although they are rarely employed during well development due to the distance between wells, limited discharge rates (i.e., limited drawdown), and short pumping duration.

Combining well-development pumping test data with other aquifer test methods (see below) will enhance the reliability of the aquifer test analysis.

A3.4.4 Single-Well Tracer Tests

Single-well tracer tests, in conjunction with depth-discrete groundwater sampling and analysis, can add a third dimension to the essentially two-dimensional results obtained by conventional sampling and hydraulic testing. Three-dimensional data can substantially improve the accuracy of groundwater flow modeling and site-specific mass transport calculations.

Two single-well tests that have proven generally useful and that have been applied at the Hanford Site are the point-dilution test and the drift-and-pumpback test. The two tests can be performed independently or combined in a single field experiment.

The point-dilution test yields a profile of hydraulic conductivity in a screened well when the concentration of a tracer (e.g., bromide) is measured as a function of both time and depth. Only a small volume of a tracer solution concentrate needs to be introduced to the well bore, and the test (conducted under natural gradient) requires no pumping. A submersible instrument for tracer measurement, test procedures, and typical results are described in Hall, 1993, "Single Well Tracer Tests in Aquifer Characterization."

The drift-and-pumpback test originally was devised as a method for estimating flow velocity independent of gradient measurement and stress tests. Like the point-dilution test, the drift-and-pumpback test is initiated by introducing a small volume of tracer to the well bore. The tracer then is allowed to migrate from the well under natural hydraulic gradient, usually for a few days or longer, depending on local conditions. Finally, the tracer slug is recovered by pumping, and the tracer concentration in the pumped effluent is monitored as a function of time (assuming constant discharge). Interpretation of the test is based on the amount of pumping required to recover the center of mass of the tracer slug.

Just as with conventional hydrogeologic analysis, the test interpretation requires an estimate of effective porosity. However, Hall et al., 1991, "A Method for Estimating Effective Porosity and Ground-water Velocity," showed that conventional test results plus the results of a drift-and-pumpback test together yield a unique estimate of the local effective porosity and groundwater velocity. Similarly, when point-dilution results are combined with the results of conventional methods, the tracer results can be recalibrated as a direct profile of aqueous mass transport.

The point-dilution calibration is valid for other wells of substantially similar construction, so the test could be used to investigate flow in those areas of the 200-BP-5 Groundwater OU where gradients are shallow and therefore ambiguous. A three-dimensional map of the rate of aqueous mass transport would be of significant benefit for locating preferential pathways.

A3.4.5 Aquifer-Pumping Tests

A multiple-well pumping test using one pumping well and several observation wells (completed in the same aquifer) is the preferred aquifer test method for determining aquifer characteristics. Aquifer properties such as transmissivity, storativity, and boundary conditions can be evaluated. Because of the logistics of discharge containment and waste handling, pumping tests generally are limited at the Hanford Site to areas with minimal to no groundwater contamination.

A3.4.6 Geophysical Methods

A3.4.6.1 Borehole Geophysical Logging

Each borehole will be logged using S. M. Stoller Corporation's Spectral Gamma Logging System (SGLS) and Neutron-Moisture Logging System (NMLS). In general, borehole logging will be performed through a single string of casing (i.e., before telescoping) over the entire length of borehole. The SGLS uses a cryogenically cooled, high-purity germanium detector to detect, identify, and quantify gamma-emitting radionuclides in the subsurface. Identification of naturally occurring and man-made radionuclides is based on detection of characteristic gamma rays emitted during decay of specific radionuclides. The SGLS is calibrated annually by measuring detector response to gamma rays from potassium, thorium, and uranium, resulting in a continuous detector response function over an energy range between 185 keV and 2.6 MeV. Verification of annual calibration before logging will ensure reliable detection and quantification of gamma-emitting radionuclides. The SGLS will be operated in move/stop/acquire mode with count times on the order of 100 to 200 seconds per data point at 1-ft depth increments. The logging data will be corrected for dead time, well-casing thickness, and the presence of water in the borehole.

The NMLS uses a 50-mCi americium/beryllium source and a helium-3 detector. Neutrons emitted from the source bombard the surrounding formation and are scattered back to the detector. Neutron moisture logs are useful as an indication of in situ moisture content and for stratigraphic correlation. The NMLS will be calibrated to provide an indication of the volumetric moisture content up to about 20 percent in 6- and 8-in.-diameter cased boreholes. For other borehole diameters, the NMLS data will be used qualitatively to identify differences in moisture content.

A3.4.6.2 High-Resolution Resistivity

HRR measures the electrical resistance of soils and is capable of profiling moisture and conductive contaminants in vadose-zone soils. Surface-based HRR has a maximum depth limit of approximately 300 ft in Hanford Site-type soils, and the results are affected by cultural noise and variations in lithology, moisture, and the nature of the contamination. Sensitivity is dependent on the resistive contrast between contaminated and unaffected sediments. Surface HRR has been demonstrated at the BC Cribs and the T Tank Farm with favorable results.

The HRR investigations are being conducted in the vicinity of WMA-B/BX/BY to support subsurface contaminant mapping efforts for the WMA. Although these investigations are not intended to directly support the 200-BP-5 Groundwater OU RI, information will be useful for assessing potential future groundwater impacts from vadose-zone contaminants at these locations.

A3.5 MONITORING OF EXISTING AND NEW WELLS

The wells currently included in the 200-BP-5 Groundwater OU groundwater-monitoring network, the current analytical suites, and the sampling frequency are listed in DOE/RL-2001-49, *Groundwater Sampling and Analysis Plan for the 200-BP-5 Operable Unit.* The planned 15 wells for the RI will be added to the groundwater-monitoring network as each is completed.

The 15 new RI wells will be sampled quarterly for the first year after installation, semiannually the second year after installation, and then annually thereafter. Biennial or triennial sampling is performed for perimeter wells that have shown stable trends for several years. Conversely, if irregular or increasing trends appear, the sampling frequency may increase accordingly.

The results of the initial sampling of the new wells will be evaluated and if the new COPC is detected above background concentrations, then a new sampling plan will be developed. The COCs not detected above background in the evaluation wells may be retained as an analyte to be sampled on a 3-year frequency (based on professional judgment) to provide evaluation of potential emerging groundwater contamination.

In addition to changes in sampling frequency, additional analytes may be added to the analytical suite for the existing monitoring wells. The implementation strategy may select specific wells in high-concentration areas and/or at wells immediately downgradient from selected waste sites to add COPCs.

Appendix B of this 200-BP-5 Groundwater OU RI/FS work plan includes a list of the wells that have been chosen for sampling. These wells are not currently being analyzed for all of the 200-BP-5 Groundwater OU COPCs and methods identified in Tables A1-10 and A1-11. It should be noted that the new wells cover most of the areas where groundwater plumes exist and should provide sufficient information of the COPCs for the 200-BP-5 Groundwater OU.

A3.6 SAMPLING PROCEDURES

Table A3-15 lists the sampling-related activities addressed by existing FH procedures. The appropriate procedure will be implemented by field personnel during performance of the sampling activity.

A3.7 SAMPLE MANAGEMENT

Sample and data management activities will be performed in accordance with FH QA program plans.

Sample preservation, container, and holding-time requirements will be specified on sampling authorization forms and chain-of-custody forms in accordance with the requirements specified in RFSH-SOW-93-0003 (or equivalent) and the specific analytical method prepared for specific sample events.

Table A3-15. Sampling Activities Conducted Using Fluor Hanford, Inc., Procedures.

Sampling Activities Before Well Construction (Fluor Hanford, Inc., Procedures)	Groundwater Sampling Activities Following Well Construction
Sampling equipment decontamination	Chain-of-custody/sample analysis request
Geologic logging	Project and sample identification for sampling services
Groundwater sampling	Field logbooks
Calibration of field equipment	Laboratory cleaning of sampling equipment
Sample packaging and shipping	Calibration of field equipment
Sampling documentation	Sample packaging and shipping
Soil and Sediment sampling	Groundwater sampling
Well development and testing	Control of monitoring instruments
Geophysical logging (S. M. Stoller procedures)	Turbidity measurements
	pH and temperature measurements
	Field analysis of conductivity

A3.7.1 Sample Custody

All samples obtained during the project will be controlled from the point of origin to the analytical laboratory, as required by Hanford Site internal laboratory QA requirements and applicable FH procedures.

A3.7.2 Sample Packaging and Shipping/Field Documentation

Field documentation shall be kept in accordance with Hanford Site internal laboratory QA requirements and FH procedures pertaining to the following:

- Chain-of-custody/sample analysis requests
- Logbooks
- Geologic logging
- Sampling documents.

A3.8 MANAGEMENT OF INVESTIGATION-DERIVED WASTE

Investigation-derived waste from these sampling activities will be handled as CERCLA waste. DOE/RL-2003-30, *Waste Control Plan for the 200-BP-5 Operable Unit*, establishes the management (e.g., designation, packaging and labeling, and storage/transportation) and disposal of investigation-derived waste generated from groundwater well sampling, aquifer testing, groundwater well installation, water-level screening analysis, geophysical logging, and equipment decontamination for 200-BP-5 Groundwater OU investigations. The anticipated waste streams associated with the activities included in this SAP are as follows:

- Miscellaneous solid waste such as filters, wipes, gloves, and other personal protective equipment; cloth; sampling and measuring equipment; pumps; pipe; wire; plastic sheeting; tools; bentonite; sand; paper; wood; construction debris; stainless steel or carbon-steel metal; and glass

- Purgewater generated during groundwater well installation, development, testing, monitoring, maintenance, and decommissioning
- Purgewater generated during decanting of soils and slurries
- Decontamination fluids
- Liquids generated during screening analysis
- Drill cuttings and associated wastes
- Materials generated from cleanup of unplanned releases
- Equipment and construction material (e.g., well casing, drill string, drive barrel, decommissioning materials, wooden pallets).

In addition to the waste control plan (DOE/RL-2003-30), a DQO summary report is being prepared to support decision-making activities as they pertain to the handling, designation, and disposition of waste derived from the installation of three groundwater-monitoring wells associated with this SAP. This waste DQO will be in place before initiation of drilling activities.

Unused samples and associated laboratory waste for the analysis will be dispositioned in accordance with the laboratory contract and agreements for return of waste to the Hanford Site. In accordance with 40 CFR 300.440, "National Oil and Hazardous Substances Pollution Contingency Plan," "Procedures for Planning and Implementing Off-site Response Actions," FH technical project lead approval is required before returning unused samples or waste from offsite laboratories.

A4.0 HEALTH AND SAFETY

All personnel working at the drilling sites addressed by this SAP will have completed, at a minimum, the following:

- Occupational Safety and Health Administration 40-Hour Hazardous Waste Site Worker Training
- Hanford General Employee Training
- Hanford Radiation Worker II training.

Work will be performed in accordance with the following procedures:

- HNF-5173, *PHMC Radiological Control Manual*
- Site-specific plans, as applicable:
  - Health and safety plans
  - Radiological work permit, as applicable
  - Activity hazard analysis/job safety analysis
  - Site-specific waste packaging instruction
- HNF-IP procedures
- Central Plateau radiological control procedures
- FH environmental procedures.

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APPENDIX B

SAMPLING AND ANALYSIS REQUIREMENTS FOR REVISED 200-BP-5 OPERABLE UNIT GROUNDWATER-MONITORING WELL NETWORK

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APPENDIX B

SAMPLING AND ANALYSIS REQUIREMENTS FOR REVISED 200-BP-5 OPERABLE UNIT GROUNDWATER-MONITORING WELL NETWORK

Table B-1. Sample Analytes and Frequency for 200-BP-5 Operable Unit Monitoring Wells. (5 Pages)

Well	Contaminants of Concern										Supporting Constituents/Measurements									
	Tc-99	Tritium	Nitrate [c]	I-129	Cyanide	Co-60	Uranium	Sr-90	Cs-137	Pu-239/240	Water Level [a, b]	Field Parameters [a, f]	Alkalinity	Am-241	Arsenic	Gross Alpha/Beta	Metals (Filtered) [d]	Np-237	TOC/TOX	Oxygen and REDOX [a]
299-E24-8		3-07	3-07	3-07		3-07			3-07			3-07			3-07	3-07				3-07
299-E26-10		A	A	A								A								A
299-E26-11		3-07	3-07	3-07								3-07			3-07					3-07
299-E27-10		3-07	3-07	3-07								3-07			3-07					3-07
299-E27-14	A	A	A	A							A	A								A
299-E27-15	A		A								A		A				A			A
299-E27-17		3-07	3-07	3-07								3-07			3-07					3-07
299-E27-18		3-07	3-07	3-07								3-07			3-07					3-07
299-E27-7	A	A	A	A							A	A			A					A
299-E28-13		3-07	3-07	3-07			3-07	3-07				3-07				3-07				3-07
299-E28-17			A				A	A	A	A	A	A								
299-E28-18		A	A	A			A				A	A			A	A				A
299-E28-2	A	A	A	A				A	A	A	A	A	A			A	A			A
299-E28-21							A					A								
299-E28-23							A	A	A	A	A	A		A		A		A		A
299-E28-24		A					A	A	A	A	A	A		A		A		A		A
299-E28-25		A	A	A			A	A	A	A	A	A		A	A	A		A		A

Table B-1. Sample Analytes and Frequency for 200-BP-5 Operable Unit Monitoring Wells. (5 Pages)

Well	Contaminants of Concern										Supporting Constituents/Measurements									
	Tc-99	Tritium	Nitrate [c]	I-129	Cyanide	Co-60	Uranium	Sr-90	Cs-137	Pu-239/240	Water Level [a, b]	Field Parameters [a, f]	Alkalinity	Am-241	Arsenic	Gross Alpha/Beta	Metals (Filtered) [d]	Np-237	TOC/TOX	Oxygen and REDOX [a]
299-E28-26	A	3-07	A	3-07			A				A	A			3-07					3-07
299-E28-27	A	3-07	A	A			A	A	A	A	A	A								3-07
299-E28-28		3-07	3-07	3-07								3-07								3-07
299-E28-5		3-07	3-07	3-07			A	A	A	A	A	A			3-07	3-07				3-07
299-E28-6		3-07	3-07	3-07		A	A	A	A	A	A	A			3-07	3-07				3-07
299-E28-8	A						A	A	A	A	A	A								
299-E32-10	A	3-07	3-07	3-07	A	A	A				A	A			3-07					3-07
299-E32-2		3-07	3-07	3-07								3-07								3-07
299-E32-4	A	A	A	A							A	A								A
299-E32-5		3-07	3-07	3-07			3-07					3-07								3-07
299-E32-6	A	3-07	A	3-07			3-07				A	3-07								3-07
299-E32-7		3-07	3-07	3-07								3-07								3-07
299-E32-8		3-07	3-07	3-07								3-07								3-07
299-E32-9		3-07	A	A	3-07						A	3-07								3-07
299-E33-12	3-07										A	A								
299-E33-13					A		A				A	A								
299-E33-15	A		A								A	A								
299-E33-16	A		A	A			A				A	A								
299-E33-18	A		A	A			A				A	A								
299-E33-26	A	3-07	3-07	3-07	A	A	A				A	A				3-07				3-07
299-E33-28	A		A								A	A								
299-E33-29	3-07	3-07	3-07	3-07								3-07								3-07
299-E33-30	A		A								A	A								
299-E33-32	3-07	3-07	3-07	3-07								3-07								3-07
299-E33-33		3-07	3-07	3-07			3-07					3-07			3-07					3-07
299-E33-334	A		A				A					A								A
299-E33-335	A									A		A								A

Table B-1. Sample Analytes and Frequency for 200-BP-5 Operable Unit Monitoring Wells. (5 Pages)

Well	Contaminants of Concern										Supporting Constituents/Measurements									
	Tc-99	Tritium	Nitrate [c]	I-129	Cyanide	Co-60	Uranium	Sr-90	Cs-137	Pu-239/240	Water Level [a, b]	Field Parameters [a, f]	Alkalinity	Am-241	Arsenic	Gross Alpha/Beta	Metals (Filtered) [d]	Np-237	TOC/TOX	Oxygen and REDOX [a]
299-E33-338	A						A				A	A								
299-E33-34	A	A	A	A	A	A	A				A	A								3-07
299-E33-35	A	3-07	A	3-07	A	3-07	A		3-07		A	A								3-07
299-E33-37		3-07	3-07	3-07								3-07								3-07
299-E33-38	A	A	A	A	A	A	A	A		A	A	A			A	A				A
299-E33-39	A	A	A	A	A		A				A	A								A
299-E33-41	A	3-07	3-07	3-07	3-07	3-07	A		3-07		A	A								3-07
299-E33-42	A			A			A				A	A								
299-E33-43	A			A			A				A	A								
299-E33-44	A					A	A				A	A								
299-E33-7	A	A	A	A	A	A	A		A		A	A				A				A
299-E34-2		A	A	A								A								A
299-E34-5		3-07	3-07	3-07								3-07								3-07
299-E34-7		A	A									A				A				A
299-E34-9		3-07	3-07	3-07								3-07								3-07
699-44-39B		3-07	3-07	3-07								3-07								3-07
699-45-42		3-07	3-07	3-07							A	A								3-07
699-47-60	A	A	A	A							A	A								
699-49-55A	A	A	A	A	A	A	A	A	A	A	A	A				A				
699-49-57A	A	A	A	A	A	A	A		A		A	A			A					A
699-49-57B	A	A	A	A	A	A			A		A	A								A
699-50-59																				
699-53-47A		A	A					A			A	A				A				A
699-53-47B			3-06					3-06			A	A								

Table B-1. Sample Analytes and Frequency for 200-BP-5 Operable Unit Monitoring Wells. (5 Pages)

Well	Contaminants of Concern										Supporting Constituents/Measurements									
	Tc-99	Tritium	Nitrate [c]	I-129	Cyanide	Co-60	Uranium	Sr-90	Cs-137	Pu-239/240	Water Level [a, b]	Field Parameters [a, f]	Alkalinity	Am-241	Arsenic	Gross Alpha/Beta	Metals (Filtered) [d]	Np-237	TOC/TOX	Oxygen and REDOX [a]
699-53-48A		A	A	A				A			A	A				A	A			A
699-53-55A	A	A	A		A	A					A	A								A
699-53-55B	A	A	A		A	A					A	A								A
699-53-55C	A	A	A	A	A	A					A	A								A
699-54-45A			3-06								A	3-06								
699-54-45B			3-06								A	3-06								
699-54-48								3-06			A	3-06								
699-54-49		A	A					A			A	A				A				A
699-55-50C	A	A	A	A				A			A	A								
699-55-57	A	A	A	A	A	A					A	A								A
699-55-60A	A	A	A	A	A	A					A	A								A
699-57-59 [e]	A	A	A	A	A	A	A	A	A	A	A	A	A			A	A		A	A
699-59-58 [e]	A	A	A	A	A	A	A	A	A	A	A	A	A			A	A		A	A
699-60-60 [e]	A	A	A	A	A	A	A	A	A	A	A	A	A			A	A		A	A
699-61-62 [e]	A	A	A	A	A	A	A	A	A	A	A	A	A			A	A		A	A
699-61-66 [e]	A	A	A	A	A	A	A	A	A	A	A	A	A			A	A		A	A
699-64-62 [e]	A	A	A	A	A	A	A	A	A	A	A	A	A			A	A		A	A
699-65-50	3-07										A	3-07								
699-65-72		3-07									A	3-07								
699-66-58	3-07	3-07									A	3-07								
699-66-64	3-07	3-07									A	3-07								
699-70-68	3-07	3-07									A	3-07								
699-72-73	3-07	3-07	3-07								A	3-07								
699-73-61		3-07									A	3-07								

Table B-1. Sample Analytes and Frequency for 200-BP-5 Operable Unit Monitoring Wells. (5 Pages)

Well	Contaminants of Concern										Supporting Constituents/Measurements									
	Tc-99	Tritium	Nitrate[c]	I-129	Cyanide	Co-60	Uranium	Sr-90	Cs-137	Pu-239/240	Water Level[a,b]	Field Parameters[a,f]	Alkalinity	Am-241	Arsenic	Gross Alpha/Beta	Metals (Filtered)[d]	Np-237	TOC/TOX	Oxygen and REDOX[a]

[a]Field measurement.

[b]Water-level measurements are to be conducted annually in July for selected wells in the 200-BP-5 Groundwater Operable Unit, as indicated in the table. In addition, water-level measurements are routinely performed whenever a well is sampled. Wells also are sampled in March as part of the Site-wide annual water-table measurements activity (PNNL-13021, *Water-Level Monitoring Plan for the Hanford Groundwater Monitoring Project*).

[c]Other anions to be analyzed in addition to nitrate include, but are not limited to, chloride and sulfate.

[d]Metals; analytes include, but not limited to, arsenic, chromium, iron, calcium, potassium, magnesium, and sodium.

[e]Guard wells; sampled annually for constituents listed above.

[f]Field parameters include pH, temperature, specific conductance, and turbidity.

A = to be sampled annually.
3-xx = to be sampled triennially (every 3 years); the "xx" indicates the first fiscal year of sampling for specified analyte in accordance with this revised sampling plan.
REDOX = Reduction-Oxidation (Plant or process) (hexone-based solvent extraction).
TOC = total organic carbon.
TOX = total organic halogens.

REFERENCE

PNNL-13021, 1999, *Water-Level Monitoring Plan for the Hanford Groundwater Monitoring Project*, Pacific Northwest National Laboratory, Richland, Washington.

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